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Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

AUGUST 1960

Prospects of MHD Power Generation . . . . . Leo Steg and George W. Sutton

Progress Report on Project Mercury . . . Charles J. Donlan and Jack C. Heberlig

Fluorine Solid Propellants . . . . . Milton Farber

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It can pinpoint a long-range missile on target. Guide a satellite or space ship to any point in the universe. Regulate the predetermined course of a surface vessel or submarine to any spot on the seven seas — by any route, however circuitous.

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This is **Hipernas,** a self-compensating, pure inertial guidance system developed by Bell's Avionics Division. Designed for the U.S. Air Force, **Hipernas** is so versatile that a whole family of related systems has been engineered for application in any environment — sea, sky, or space.

The system introduces new Bell BRIG gyros. Its accelerometers and digital velocity meters are already operational in missile and space guidance systems.

Hipernas — and many other systems such as the Air Force GSN-5 and the Navy's SPN-10 All-Weather Automatic Landing Systems — typify Bell's capabilities in the broad field of electronics. This diversity of activities offers an interesting personal future to qualified engineers and scientists.

Avionics Division

BELL AEROSYSTEMS COMPANY

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When crews of SAC's 1st Missile Division successfully launched the USAF ICBM Atlas from Vandenberg Air Force Base, September 9, 1959, the world became aware that the United States had brought into being a formidable retaliatory power for peace. Within four months after the first operational launch, the Air Force doubly underlined this missile's capability. On a single day, January 26, 1960, the 16th and 17th consecutive successful Atlases were fired intercontinental ranges to predetermined targets from both Atlantic and Pacific bases.

After only five years of intensive development, including concurrent research, testing and fabrication under this nation's top military priority, Atlas is extremely versatile as well as powerful. It was the Project Score satellite vehicle and is scheduled for use in Project Mercury, the Man in Space Program, and in other space exploration missions. Thus, used as a booster for space projects, Atlas provides the nation with a key capability in scientific as well as military applications.

Space Technology Laboratories provides the systems engineering and technical direction for the Atlas as well as other portions of the Air Force Ballistic Missile Program. Much of what was learned in building Atlas has helped cut the lead-time in the development of such other Air Force Ballistic Missiles as Thor, Titan and Minuteman.

Among the industrial organizations which have worked in concert in developing Atlas are such major contractors as: Convair, Division of General Dynamics Corp. for airframe, assembly and test; General Electric Co. and Burroughs Corp. for radio guidance; Arma, Division of American Bosch and Arma Corp. for inertial guidance; Rocketdyne Division of North American Aviation, Inc., for propulsion; General Electric Co. for re-entry vehicle; Acoustica Associates for propellant utilization.

America's first intercontinental ballistic missile...is helping to bear the burden of today's power for peace

ATLAS

The continuing development of Atlas as well as other USAF missiles and related space probes, has created important positions on STL's technical staff for scientists and engineers with outstanding capabilities in: thermodynamics, aerodynamics, electronics, propulsion systems, structures, physics, computer technology, telemetry, and instrumentation. If you believe you can contribute in these or related fields and disciplines, you are invited to send your resume to:

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Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY INC

August 1960 volume 5 number 8

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ASTRONAUTICS is published monthly by the American Rocket Society, Inc., and the American Interplanetary Society at 20th & Northampton Sts., Easton, Pa., U.S.A. Editorial offices: 500 Fifth Ave., New York 36, N. Y. Price $9.00 a year; $9.50 for foreign subscriptions; single copies $1.50 Second-class postage paid at Easton, Pa. This publication is authorized to be mailed at the special rates of postage prescribed by Section 132.122. © Copyright 1960 by the American Rocket Society, Inc. Notice of change of address should be sent to ARS, 500 Fifth Ave., New York 36, N. Y., at least 30 days prior to publication. Opinions expressed herein are the authors and do not necessarily reflect those of the Editors or of the Society.

Theoretical Concept is Turned into Hardware

Honeywell Develops a Practical

Mr. Robert Maze, Chief Engineer of Honeywell's Marine System Group, is reflected in the highly polished beryllium spherical rotor of Honeywell's new Electrically Suspended Gyro. The Marine System Group is a special Honeywell "task force" assigned to guide the ESG program through its rapid development.

Electrically Suspended Gyro!

Advanced new gyro concept using friction-free spherical rotor will bring greater accuracies to marine and airborne inertial systems, and northfinder systems.

Honeywell's leadership in the field of inertial systems and sensors is further demonstrated with advances on its Electrically Suspended Gyro. Here the company has taken a theoretically superior gyro concept, conceived by Dr. Arnold Nordsieck of the Univ. of Illinois, and turned it into practical development hardware. This new ESG concept is being developed under funding from the Navy Special Projects Office and Wright Air Development Division. Recognizing the unique capabilities of this new device, Honeywell has assigned a special task force group to continue to press the development of the gyro and the inertial system designed to take fullest advantage of the gyro's capabilities. In the near future, the Honeywell inertial system incorporating the ESG will be put into its test phase.

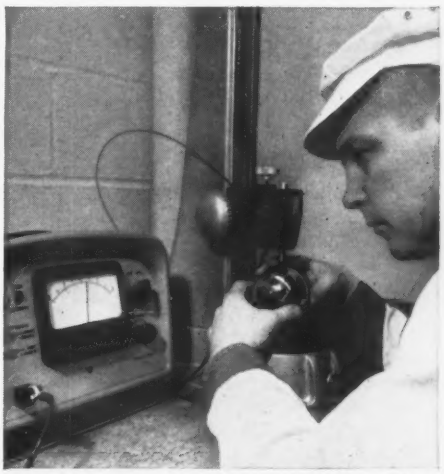
This new gyro has only one moving part, a spherical rotor, electrically suspended in a self-contained, hard vacuum to completely isolate the sensing element. The spherical rotor is made of beryllium, machined and polished to tolerances of a few millionths of an inch! The gyro is brought up to speed by electronic means, then coasts throughout long periods of operation. Reference information is picked off optically.

Honeywell, because of its experience in gyro components and systems, has already solved many problems related to this new gyro concept.

1. **Precision Machining of Problem Metals:**
   In order to take advantage of beryllium's high material stability, Honeywell has developed manufacturing techniques that overcome beryllium's brittleness and toxicity problems.
2. **Precision Ceramics:**
   Honeywell has perfected the techniques for firing and machining the precision ceramic envelope, and for overcoming the difficulties in fabricating the ceramic-to-metal seals.
3. **System Integration:**
   Honeywell, with its advanced system experience, has created a new inertial system to take fullest advantage of the capabilities of this new Electrically Suspended Gyro.

For more information on Honeywell's new products, write to Minneapolis-Honeywell, Dept. AG-8-111, Minneapolis 8, Minn.

Precision ceramic envelope receives a final machining after being fired at a temperature of 1300° C. Diamond grinding and ultrasonic drilling are utilized in finishing the envelope.



Beryllium rotor, after being machined, ground and polished, is checked for sphericity to tolerances of a few millionths of an inch!

Honeywell

Military Products Group

Astro notes

MAN IN SPACE

• NASA is hammering out its program upstream of Mercury at this writing. A few trends are now apparent. Most important is a decision to abandon the Atlas-Centaur as a bootser for a manned space vehicle. NASA's next manned vehicle after Mercury will be a multiman space observatory launched by Saturn. NASA will not pursue Centaur because it is a "dead-end street," according to one of its officials.

• Centaur will be utilized, however, in the advanced man-in-space program to develop re-entry vehicles with a lift shape. It will be capable of testing the basic "module" of the Saturn system—the escape, re-entry, and recovery vehicle for the crew. This vehicle will also have control and communications capability.

• It is possible Saturn will also be pressed into service for upstream man-in-space vehicle experiments even before it is ready for operational use. Since the last four Saturns of the 10-vehicle test program will have all-live stages, they will have a payload capability far in excess of that needed for their own test instrumentation. As a consequence, NASA is studying the possibility of using them to stage reentry trajectories at escape velocities—such as would be required for a manned circumlunar vehicle returning to earth.

SATURN, NOVA, KIWI

• The initial series of Saturn booster static firings was completed with a run of 122 sec on the "battleship" model at the Huntsville test stand. This was the eighth and longest Saturn static firing. This month a new series of static tests will begin of the Saturn booster scheduled for actual flight test from Cape Canaveral next summer. This booster is nearing final assembly at the Marshall Space Flight Center.

• The Nova rocket configuration is to be "clarified" this year. The Von Braun team favors nuclear upper stages for the Nova, retaining the 1.5-million-lb-thrust chemical engines in the lower stages. Dr. Von Braun brushes aside suggestions that the C-2 four-stage Saturn will be adequate for future space missions, including manned lunar and interplanetary missions, by virtue of its ability to put 45,000 lb in a 300-mile orbit. "You could fly the Berlin Airlift with DC-3's," he observed, "but DC-4's are really more efficient."

• The AEC successfully tested the new Kiwi-A Prime nuclear-powered rocket engine at Jackass Flats. It pumped hydrogen through the engine for 5 min while the reactor was close to full power. The prototype powerplant will be dismantled and its components carefully examined before a final evaluation of the performance. Later this summer, the AEC will conduct much more severe tests on Kiwi-A3 to determine just how far a nuclear rocket engine can be pushed.

PIONEER V

• America's far-ranging Pioneer V space probe sent its last message to earth on June 26, when it was 22, 462,740 miles from the Jodrell Bank receiving antenna. In its active 106 days, the 95-lb planetoid established new distance records for tracking, receipt of telemetry, maintenance of human control, and magnetic and radiation measurements in space. Its important scientific contributions have been reported previously in Astro Notes.

• Battery failure resulting from a slow leakage into the vacuum of space appeared to be the most probable cause of the probe's malfunction, since Jodrell Bank still had several decibels of tracking capability in hand at the 5-watt level when it failed to respond. Its radio propagation behavior was curious in two respects. Its signal strength seemed in some way linked to solar activity, improving several decibels just at the onset of solar flares, and the duration of its transmissions picked up strongly just before it ceased operation. NASA is studying both phenomena.

SATELLITES

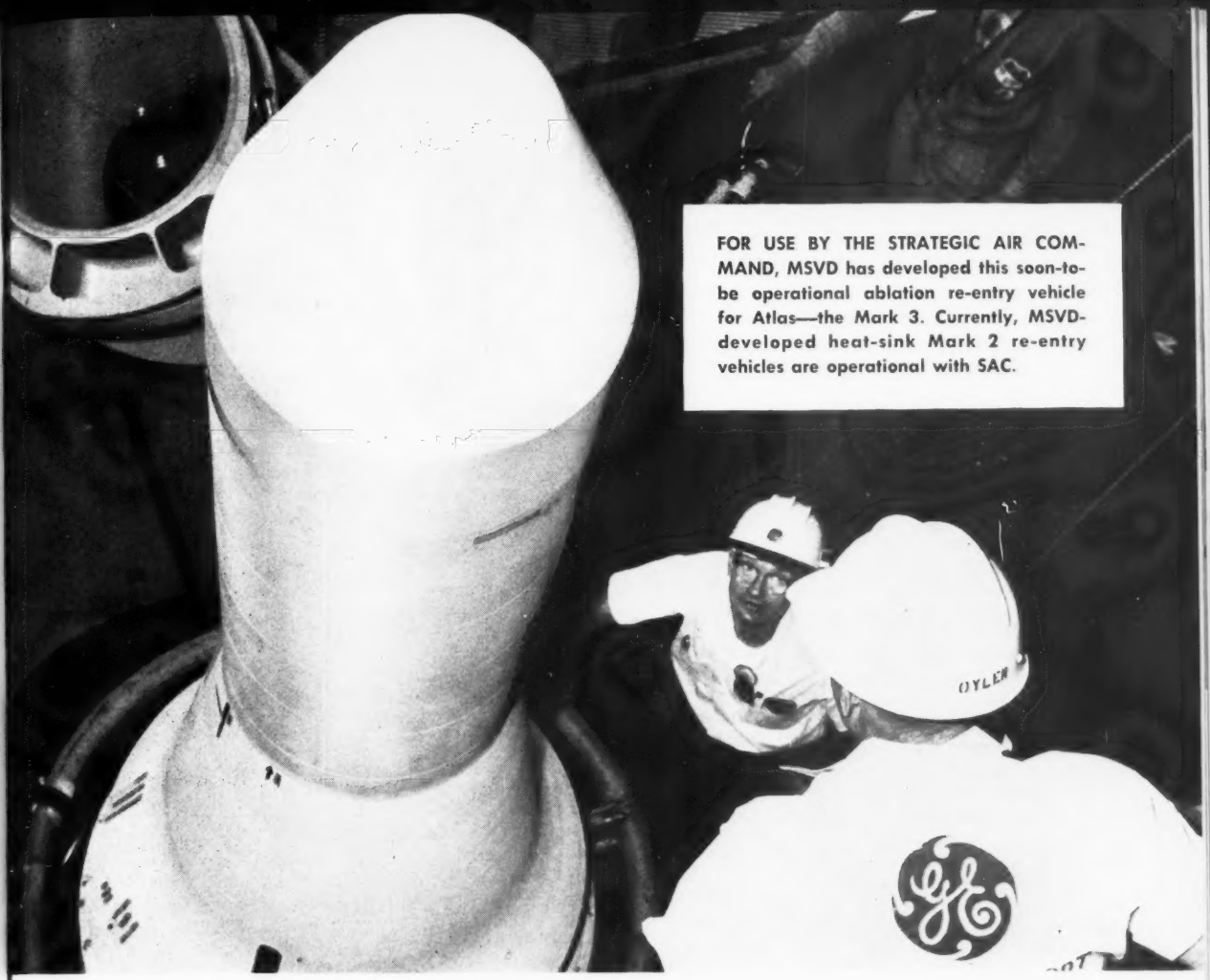
• The Navy jolted Washington space hands with its two-in-one satellite in June, the Transit II-A navigation experiment (223 lb) and the solar radiation experiment (42 lb) devised by Herbert Friedman of NRL. At one stroke, the shot appears to put the Navy back in the space science business in a bigger way than it was when it controlled the entire show. This is no small accomplishment, for the Navy must now rely on the AF for its boosters (Thor-AbleStars) and the National Space Act specifically assigns to NASA responsibility for scientific investigations in space.

• The AF also established a considerable precedent in launching Transit II-A. It placed the payload in an orbit inclined 65 deg in a launching from Cape Canaveral, which means the rocket imperiled Cuba, Jamaica, Colombia, and the rest of South America in its trajectory. The State Dept., not notified of the trajectory in advance, is still petrified at the consequences a Cuban landing would have had. (The most inclined orbit fired previously from Cape Canaveral was less than 54 deg to avoid passing over a tip of Newfoundland.)

• For the first week of its life in orbit, the Transit experiment remained in abeyance to accommodate a preliminary Canadian experiment on the intensity of galactic radio noise at 3.8 mc. Depending upon the intensity of this radio background, the Canadians will select either a 1- or 10-watt radio transmitter system for their ionospheric topside sounder, to be launched by an NASA Thor-Delta rocket. At the end of the Canadian experiment, the heavy antennas were released at the end of wires to despin the satellite, and the Navy doppler-navigation experiment commenced.

• Explorer VII has lost one of its four radio telemetry channels and three experiments it transmitted—exposed solar cell, heavy cosmic rays, and Herbert Friedman's Lyman-Alpha experiment. Still operating are the Van Allen radiation and Suomi heat balance experiments plus the temperature measurements. The entire satellite is supposed to quit Oct. 13, a year after its launching.

• NASA has revamped its Thor-Delta program with a decision to fire all the remaining eleven vehicles from Cape Canaveral. Initially, it planned to launch the last five from Vandenburg AFB, Calif., but it has decided that the cost of moving the launching and support facilities is unwarranted in view of the flexibility of the Thor-Agena systems, which will become avail-



FOR USE BY THE STRATEGIC AIR COMMAND, MSVD has developed this soon-to-be operational ablation re-entry vehicle for Atlas—the Mark 3. Currently, MSVD-developed heat-sink Mark 2 re-entry vehicles are operational with SAC.

MISSILE AND SPACE VEHICLE DEPARTMENT

...center for missile and space technology research and development at General Electric

Progress in payload delivery for SAC

Today, as a vital part of SAC's deterrent weapon mix, Mark 2 operational re-entry vehicles developed by the General Electric Missile and Space Vehicle Department stand ready—helping to guard the peace of the Free World.

Continuing its progress under the direction of the Air Force Ballistic Missile Division, MSVD has developed an even more advanced re-entry vehicle—the Mark 3—which soon will be operational with SAC's missile squadrons. The Mark 3's payload delivery capability was dramatically demonstrated just 4 weeks ago when it successfully survived a 9,000 mile trajectory—longest re-entry vehicle flight in the world to date.

Now MSVD is designing and will build the re-entry vehicles for SAC's newest air-launched ballistic missile, the GAM-87A, SKYBOLT.

Hand-in-hand with this re-entry vehicle progress, MSVD has designed and developed items of re-entry vehicle ground support equipment for SAC. Latest of these is the air-suspension mating trailer, now being produced for SAC's use on both Titan and Atlas missiles.

Through such programs, MSVD continues to help increase the deterrent capability of SAC—strongest power for peace in the world today. Missile and Space Vehicle Department, General Electric Co., Philadelphia 1, Penna. 160-94

GENERAL ELECTRIC

MISSILE AND SPACE VEHICLE DEPARTMENT

A Department of the Defense Electronics Division

Scientists and Engineers interested in career opportunities in Space Technology, contact Mr. T. H. Sebring, Dept. 160, MSVD

able toward the end of the Delta program. The next Delta shot (this month)) will be another Echo 100-ft communications sphere.

• Launching of the first Courier communications satellite was scheduled last month from Cape Canaveral aboard a Thor-AbleStar. Payload will measure more than 4 ft in diam and weigh about 500 lb. It will have five tape recorders with a memory capacity of 6 million bits and will be able to move information at 44,000 bits a minute.

• The Most brilliant performer of all NASA satellites to date—Tiros I—retired from the scene July 1, after three months of almost perfect operation in which 22,952 vidicon images of earth's cloud cover were transmitted to receiving stations at Kaena Point, Hawaii, and Ft. Monmouth, N.J. Tiros I, besides leading to theoretical advances in meteorology, provided "real-time" weather information—perhaps the first "practical" application of a satellite up to its appearance. Anxious to exploit the potential of weather satellites, the AF announced plans to rush into being, within two years, a full-scale ground system for processing data from Tiros satellites and providing synoptic weather predictions based on it. The Budget Bureau turned down a request for $\$2^1/_2$ million for this purpose a year ago.

SPACE SCIENCE

• Scientists are starving for meteoritic material, according to the Smithsonian Institution, since most of the U.S. supply of meteorites has been sacrificed for astrophysical research. It announced it will serve as a central clearing house for a continent-wide collecting program in hopes of pushing meteorite finds from one to five per year. Meteorite finds to date have provided the most important body of scientific information on the origin of the solar system.

• The AF will fire 33 rockets from Eglin AFB, Fla., to investigate the production of artificial ionospheres and their use for propagation of radio signals. The rockets will inject a variety of chemicals into the atmosphere at altitudes ranging from 37 to 280 miles. Called "Project Firefly," the series of shots is expected to produce ionized clouds 6–9 miles in diam, generally visible on the ground. (See Murray Zelikoff's article in the July 1959 *Astronautics*, page 46.)

SPACE TECHNOLOGY

• NASA will try again this month to orbit the moon with a payload launched by an Atlas-Able. A backup flight is scheduled in November. The shots are repeats of last year's abortive attempt on Thanksgiving Day to orbit the moon with a 372-lb package. The new series will drop the TV scanning device and change from a 5- to a 2.5-watt transmitter. It will retain the radiation and magnetometer experiments, as well as the important technological experiment involving a maneuvering capability in space. The spinning payload will have fore and aft rocket nozzles plus a tank of hydrazine to provide 30,000 lb-sec of impulse. It will be capable of four accelerations and two retrofirings, presumably sufficient to achieve a lunar orbit.

• Two aerodynamic scale models of Dynasoar and three scale models of Dynasoar structures will be prepared by Flight Sciences Laboratory of Buffalo, N.Y., and the McDonnell Aircraft Corp., respectively, under recently announced AF contracts. Expected to be ready for flight testing within a year, models would be boosted by the AF version of Scout, HETS-609A, now entering a series of nine developmental tests at Cape Canaveral. These are the first of several developmental Dynasoar studies to employ models. Advance studies are in progress of the next step beyond Dynasoar as an orbital glider—a lift-developing vehicle that can re-enter at speeds up to escape velocity.

• The field of space power systems continues to expand rapidly. The Martin Co. announced that it is testing a 125-watt auxiliary power unit called Snap IA (see page 88). The AF (WADD) contracted with the Hamilton Standard division of United Aircraft Corp. for a solar power generator, to be built first as a 100-watt model, and then as a 1500-watt operational unit for satellites in 90-min earth orbits. The 1500-watt unit would employ some 7000 small aluminum reflectors, covering an area of 700 sq ft, to focus sunlight on a collector-thermocouple system. This generator, folded, would automatically open in space. The Garrett Corp.'s AiResearch Mfg. Div. received the AF's prime contract on Spur, the 300-kw nuclear-powered generator system. AiResearch will develop a two-loop nuclear power conversion system using a saturated-vapor Rankine cycle for Spur. Aerojet-General Nucleonics is subcontractor for the Spur liquid-cooled reactor, and Westinghouse the generator equipment.

• Armour Research Foundation has developed an ozone analyzer for AFCRC based on the design proposed by Francois Olmer of ARF. The analyzer is expected to contribute to both atmospheric and human-factors studies.

• Raytheon will study and plan instrumentation for a space-vehicle recovery control center to be established at the AF Flight Test Center, Edwards AFB, Calif., and used in the Dynasoar program.

• Bendix's Radio Div. will construct a five-story demonstration model of the computer-controlled ESAR, Electronically Steerable Array Radar, under a $4-million contract with the AF's Rome Air Development Center and ARPA, with which the company has been working on advanced radar techniques. ESAR will be able to track simultaneously and differentially space vehicles (launched from Wallops Island) and aircraft.

• In another radar advance, Sperry-Pheonix announced that it has developed a ground-based microwave system (MAN) that can automatically track, steer, and spot-land maneuverable space vehicles. The basic system, which employs a single radar frequency, was worked out by Sperry for the AF as a means of controlling high-speed drones and missiles.

• Helicopter-like rotary wings will be studied by Kaman Aircraft for controlling descent of recoverable space vehicles under a half-million dollar contract let by WADD.

• Development of a million-lb-thrust segmented solid-propellant booster under AF's Project 3059 went to Aerojet-General, with a Fiscal Year 1961 contract of some $4 million. Grand Central Rocket was awarded a supporting contract, much smaller, for related work on the motor.

• NASA chose Space Technology Laboratories, McDonnell Aircraft, North American Aviation Missile Div., and Hughes Aircraft to make five-month competing studies of a 3-ton lunar soft-landing vehicle. An extension of the initial Project Ranger, the first soft-lander would probably be launched by Centaur in 1963.

THRUST TERMINATION

Complete Missile & Space Vehicle Ordnance Systems

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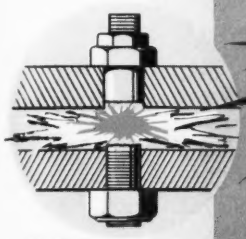
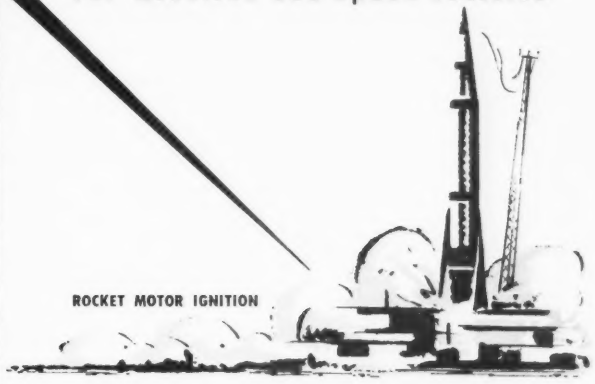
Complete XB Systems Capability For Missiles and Space Vehicles

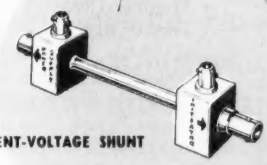


STAGE SEPARATION BOLT



ROCKET MOTOR IGNITION

MISSILE DESTRUCT



XB CURRENT-VOLTAGE SHUNT

McCormick Selph Associates, after two years intensive study and development of high voltage power supplies, now offers a complete exploding bridgewire systems capability: available as complete missile and space vehicle XB ordnance systems (power supplies, transmission line and XB ordnance) or as separate components and devices. The Mc/S/A power supply uses no spark gap or thyratron high-voltage switches, charges condensers below minimum breakdown potential of air (< 327 volts), uses light and compact electrolytic condensers and has a controllable discharge rate.

Mc/S/A's approach provides wide versatility of application.

- POWER SUPPLIES
- EXPLOSIVE BOLTS
- XB CURRENT-VOLTAGE SHUNT
- INITIATORS
- IGNITERS
- PRESSURE CARTRIDGES

To separate the characteristics of the XB initiator from the power supply, Mc/S/A has developed a current and voltage measuring shunt to be used in conjunction with dual-channel recording oscilloscopes. This dynamic test instrument provides voltage and amperes vs. time oscillograms at the XB initiator and permits accurate analysis of initiation characteristics separately from power supply and transmission line.

Contact Mc/S/A Applications Engineering Department with your specific XB systems or components requirements.

EXPLOSIVE ORDNANCE

McCormick Selph Associates

HOLLISTER AIRPORT/HOLLISTER, CALIFORNIA

SPACE ORGANIZATION

• Roswell Gilpatric (see page 18), former USAF assistant secretary, will be chairman of Aerospace's Board of Trustees; and Ivan Getting, vice-president of Raytheon, will be president of the company.

• Robert C. Seamans Jr. of RCA replaced Richard Horner as associate administrator of NASA.

• NASA set up a new Launch Operations Directorate under Kurt Debus to coordinate NASA firings at the Atlantic and Pacific Missile Ranges, subject to special limitations on Project Mercury.

MISSILES

• The AF expects to test an all-live Minuteman on its very first free flight of the missile this year. Not only that, but the three-stage bird is scheduled to lift off its Cape Canaveral pad with the Autonetics guidance system aboard. This all-out testing procedure may be an important factor in the AF's confidence the weapon will be operational at Malmstrom AFB, Mont., by mid-1962. (Malmstrom, ironically, was a lend-lease transportation base with the Soviet Union in WWII.)

• That 9000-mile Atlas shot into the Indian Ocean in May didn't cut the mustard after all. Though the impact was reasonably accurate, the telemetry quit about 30 sec before impact. Analysis of the available record indicates the magnesium structure of the GE nose cone was on fire. A nuclear warhead could not have survived the experience intact.

• Nose-cone builders are upset because the AEC is interested in building the nose cone for Martin's Titan II, the SM-68B. General Electric and Avco fear the AEC wants to "capture" the nose-cone business for itself in line with its long tradition of manufacturing weapons and related materials.

• The Navy brought development of the Corvus air-launched standoff missile to a halt in anticipation of more advanced weapons. The project, under prime contract to Temco, had run to $80 million.

• The Pentagon dropped plans to use a Jupiter target for testing the Nike-Zeus antimissile. Instead, it has told the Army to buy 18 Atlas missiles and fire them 4800 miles from Vandenberg AFB to the vicinity of Kwajalein, where the Nike-Zeus test site will be located. The decision cost $7.5 million, $6 million to Chrysler for Jupiter missiles and $1.5 million for construction on Jupiter launching facilities on Johnston Island.

• In another switch, the Pentagon reshuffled the role of Nike-Hercules in the nation's air defense pattern. It shifted Nike-Hercules batteries intended for defense of Hanford, Wash., and seven SAC bases to seven metropolitan areas: Washington-Baltimore, Los Angeles, Philadelphia, New York, San Francisco, Chicago, and Detroit. The Hercules, which has nuclear capability, will replace 15 Nike-Ajax batteries in these areas.

• Army Ordnance has awarded Bulova Research Corp. a $46,000 contract to study guidance problems of a missile capable of being fired from a recoilless rifle. It's called Project Polecat.

• The Subroc missile has cleared its booster-separation and water reentry tests, and will be subjected to underwater launching tests this fall. Subroc is a depth charge capable of being rocket-launched by a submarine from its torpedo tubes, traveling to the surface, and then through the air to the vicinity of its target, where it re-enters the water again. Range—35 miles plus.

• The propulsion system for the E-series Atlas will develop 389,000 lb thrust at sea level, besides being lighter and simpler in design than the present one. Rocketdyne, which produces the E-series powerplant (designated MA-3), has pointed out that an advanced version of the H-1 engine for the Saturn booster eliminates pressure regulators and solenoid valves entirely, whereas the first engines it produced for IRBMs in 1956 had as many as five pneumatic pressure regulators and 17 solenoid valves for start and shutdown. The H-1 engine requires electrical signals just twice, once for start and once for stop.

• GE and Nord-Aviation signed an agreement giving GE the right to build the Nord-developed SS-10 and SS-11 wire-guided antitank missiles in the U.S.

• Semper-missile studies will be made by Advanced Technology Corp., a subsidiary of Electronic Communications Inc., under the technical direction of the Naval Missile Center, Pt. Mugu, Calif.

• With its own funds, the Martin Co. will evaluate 17 weapon systems, including eight of its own, to develop a 15-year master plan of ground checkout systems for manned and unmanned weapons. The study is one of several sponsored by ARDC. It will set design standards and define checkout-system requirements through 1975.

R&D

• An indication of the growing weight NASA is carrying among Space Age contractors can be seen in recent contract bidding. Forty-three companies attended JPL's bidder's conference on a soft-lunar-landing vehicle for Centaur, and 90 companies have requested specifications for NASA's orbiting astronomical observatory, which is scheduled for launching by an Atlas Agena-B in 1963.

• Noting that most authorities in the field believe that incorporation of the fluorine atom in solid propellants offers the best prospect for dramatically upping their performance, Allied Chemical announced that its contract with ARGMA to study high-energy oxidizers for advance solid propellants has been extended for a year, the total program coming to $1.4 million. Milton Farber discusses fluorine solid propellants on page 34. Allied sees chlorine trifluoride as a strong contender among storables.

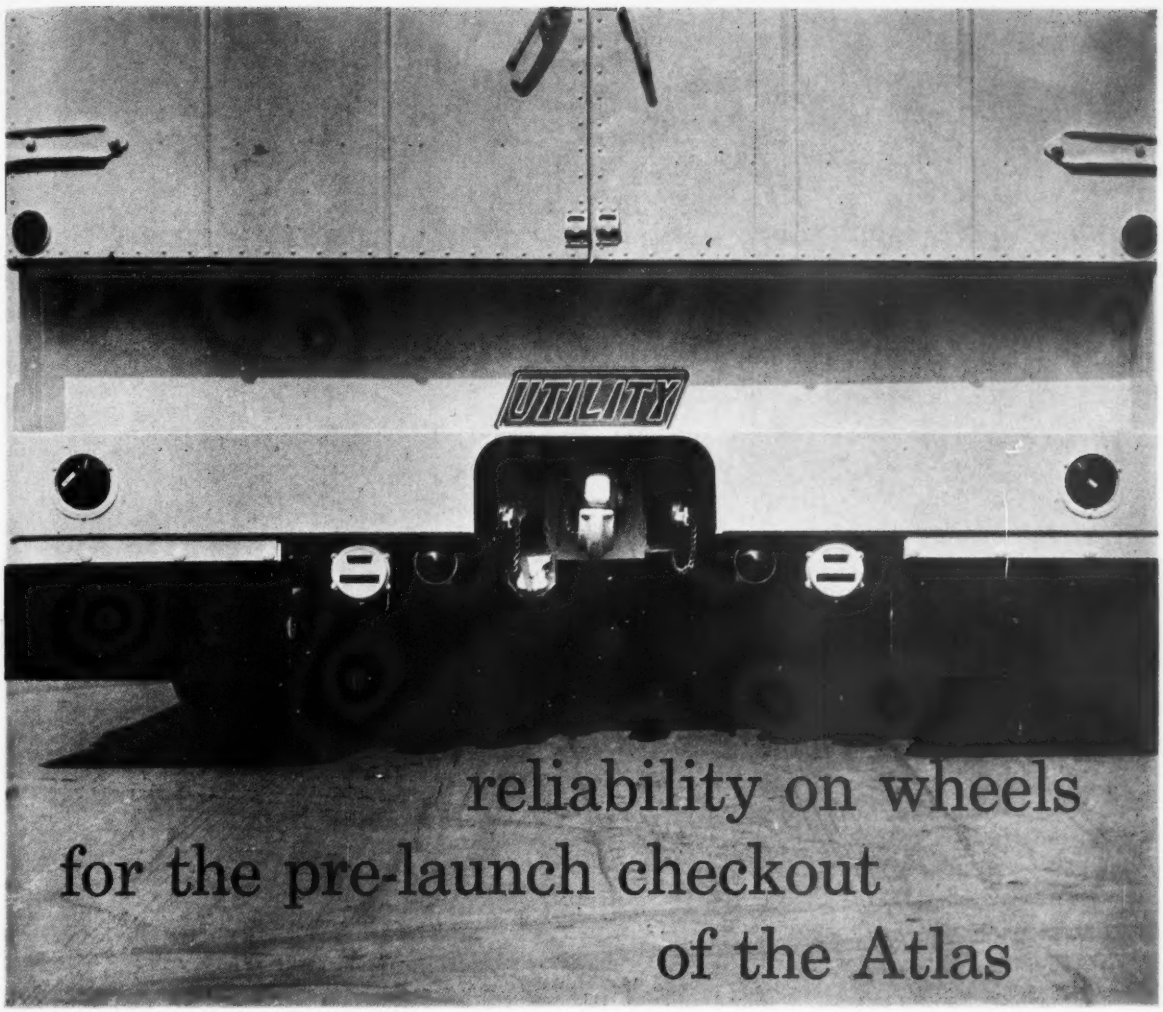
• Some 150 representatives of leading government and private agencies engaged in the development, manufacture, and test of advanced solid propellants met at the Army Ordnance Missile Command July 12 for a three-day seminar on safety.

• Hughes Aircraft announced the first true amplification of light, and their version of the tool for this purpose, the Laser. Harold Lyons of Hughes Research Laboratory discussed the Laser in his article in the May 1960 *Astronautics*. Bell Telephone Labs is also doing Laser research, like Hughes, with its own funds. ARPA awarded a contract for close to a million dollars late in June to TRG, Inc., for continued work on Lasers.

• Aerojet-General static-fired successfully a liquid hydrogen-liquid oxygen engine designed to develop 200,000-lb thrust. The test engine contained all the major components required by an operational version.

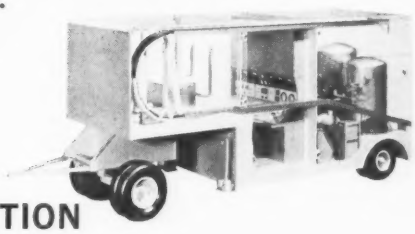
• An atomic reactor, the Triga Mark F, capable of providing short pulses of intense nuclear energy for

(CONTINUED ON PAGE 16)



reliability on wheels for the pre-launch checkout of the Atlas

CV-A Part No. 27-08239-1 is another way of saying accurate, reliable ground support equipment – mounted on a trailer for mobility. Designed for Convair-Astronautics, this CSC system is used in the pre-launch checkout program for the Atlas missile. Packaged in a standard-size, highway semi-trailer, the pneumatic, dynamic system provides all necessary manual and automatic controls and an air-conditioned control room for operating personnel. Repeatability and reliability were the most important design criteria for the system, which is fully described in CSC Bulletin 3025-X3.



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"Mein Herr, jawohl, durch...

$$\psi(x) = \frac{1}{\sigma(2\pi)^{\frac{1}{2}}} \exp\left(-\frac{1}{2}\ \frac{x^2}{\sigma^2}\right)\ldots"$$

"El próximo año

$$P = \frac{A}{A\text{-}B} E_{N,A} - \frac{B}{A\text{-}B} E_{N,B} \ldots"$$

"S'il

$H(x$

7200 idea-exchangers i4 c

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"S'il vous plaît...

$$H(x) = \sum_{i}^{n} p_i \log \frac{1}{p_i} = -\sum_{i}^{n} p_i \log p_i \ldots"$$

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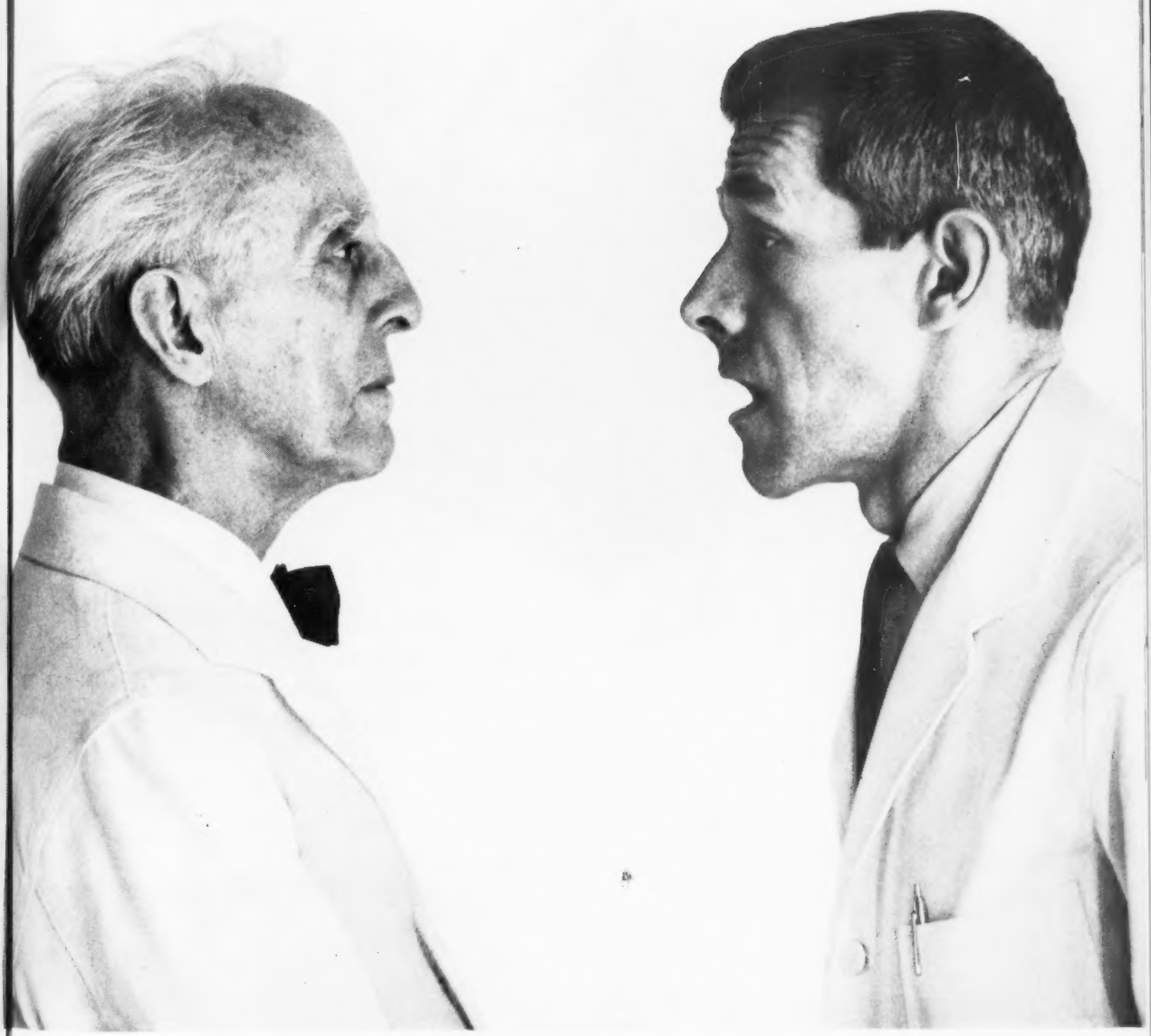
of infinite value to us.
In a few years, I think fully
automated post offices are going
to be as American as apple π."



4 countries work for ITT.

atellite system that could make worldwide TV a matter of a few
ears. As a signal can be bounced from one planet to another,
o can an idea grow in bouncing from one mind to
nother. International Telephone and Telegraph
orporation, 67 Broad Street, New York 4, N. Y.

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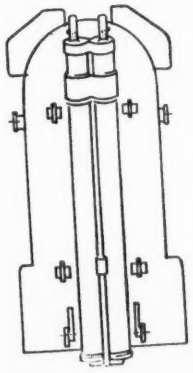
ESCAPE WITH SAFETY AT

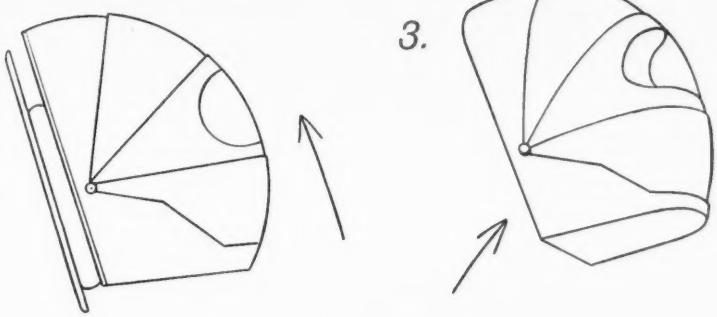
1.



THIOKOL'S ADVANCED ENGINEERING SKILLS HELP ANSWER ANOTHER SPACE AGE PROBLEM... NOW PILOT EJECTION FROM AIRCRAFT MOVING AT MACH 2 OR BETTER.

ESCAPE CAPSULE DEVELOPED BY STANLEY AVIATION CORP. FOR THE CONVAIR B-58 IS POWERED BY UNIQUE LOW THRUST ROCKETS SPECIALLY DESIGNED BY THIOKOL

SUPERSONIC SPEEDS !



$$m\ddot{y} = F_y - \alpha W\cos\chi - \mu(|N_1| + |N_2| + |N_3|) + F_t + F_R\cos\phi \quad \cdots\cdots \quad y \ll (l_n - d_z)$$

$$I_B\ddot{\theta} = M + F_y d_{11}\cos(\beta+\theta) + F_x d_{11}\sin(\beta+\theta) - F_R d_B \sin(\phi-\theta) - \alpha W d_{12}\cos(\chi+\lambda+\theta) - m\ddot{y} d_{12}\cos(\lambda+\theta)$$

$$m[\ddot{y} + d_{12}\ddot{\theta}\cos(\lambda+\theta) - d_{12}\dot{\theta}^2\sin(\lambda+\theta)] =$$

$$\underline{V}_c = iu + jv + kw$$

$$\underline{\Omega}_c = ip + jq + kr$$

$$F = m\frac{(\delta \underline{V}_c)}{(\delta t)}$$

$$F_x = m(\dot{u} + wq - vr)$$

$$F_y = m(\dot{v} + ur - wp)$$

$$F_z = m(\dot{w} + vp - uq)$$

Fig. 1. Pilot sits and works in escape unit. THIOKOL two-barrelled catapult powered by dual rocket engines attached to back of capsule.

Fig. 2. At start of escape cycle, THIOKOL slow burning propellant activates catapult. Acceleration control built into propellant saves occupant from injury. Capsule is propelled from airframe.

Fig. 3. Rocket motors, ignited automatically at end of catapult stroke, propel capsule to safe area above airframe—clear of vertical tail. In high or zero altitude escape, capsule attains sufficient height for parachute to open and arrest fall.

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the study of radiation effects on electronic equipment, will be produced for the Diamond Ordnance Fuze Laboratories by General Dynamics; design and construction of the reactor and associated facilities will be done by its General Atomics Div. in San Diego.

• Rocketdyne proposes a solid-propellant rocket motor for drones that would have variable thrust and long burning time. An extension of its work on the Teal, the motor would utilize the company's variable-area nozzle and ammonium nitrate-based propellant.

• Rocket sleds came in for a little news lately. A $2^1/_2$-ton monorail sled powered by Nike boosters, which are produced by Hercules Powder, reached a velocity of 2650 mph on the Holloman track, reputedly a record for this class of sled. The 48-ft model took $5^1/_2$ miles of the 7-mile track in 15 sec. Aerojet-General has designed a sled for its new controlled-thrust liquid-propellant engine. With an initial weight of 9 tons, the sled would accelerate a 3000-lb payload to Mach 2 and decelerate at up to 20 g. Cook Electric will design and build a supersonic parachute-test sled under contract with WADD for the 4-mile track at Edwards.

• Aerojet's Ordnance Div. reports the development of an improved flare composition with burning time unaffected by altitudes to 40,000 ft and increasing only 40 per cent between 40- and 70-thousand ft.

• Reductions of switching time and collector resistance in diffused-base transistors—by a factor of more than 10 have been realized at Bell Telephone Labs through epitaxially grown films. This development, according to the Labs, should have far-reaching implications for both fabrication and application of semiconductor devices.

• Amplifying its work on space communications, the Bell Telephone System outlined a plan for a worldwide telephone and TV network based on a system of some 50 satellites in polar orbit before the Federal Communications Commission. The company estimated that basic facilities for 600 telephone circuits and for TV service among 13 pairs of worldwide terminals would total about $170 million. Bell would expect to share the cost of launching and maintaining the communication satellites.

• With the awarding of a $\$15^1/_2$ million contract to GE's Defense Systems Dept. to develop and install its Mistram system near the AFMTC's Cape Canaveral Missile Test Annex, the AF took steps to provide a trajectory-measurement system commensurate with the needs of coming classes of space vehicles as well as missile systems. Mistram is a radio interferometer with 10,000- and 100,000-ft baselines, made possible by the work of DSD's Lewis J. Neelands on phase stabilization of electrical links between outlying receivers and a central station that provides real-time data outputs. Mistram will have essentially hemispherical coverage for ranges greater than 1000 miles when tracking the transponder on a vehicle moving at velocities as high as 50,000 fps. This is the kind of tracking system that should be able to help control the re-entry of lunar and interplanetary vehicles, as well as follow them with great precision. GE engineers commented that the initial system would be able to track a vehicle with a 14-in. flush-mounted antenna to a distance of the moon. The initial system should be ready for evaluation tests in January 1962, according to GE, with a more advanced installation, incorporating the initial one, planned as a successor. As geographical positioning of Mistram introduces the second greatest uncertainty in its measurements—the first being the uncertainty in the free-space velocity of light—GE has proposed to the AF a satellite that would refine Mistram positioning.

CONTRACT BRIEFS

• Contract funds flowed into major missile programs last month, the largest increment being $247 million (AF) to Boeing for the Minuteman development through December 1961 . . . Remington Rand Univac received $26 million (AF) for production and testing of ground computers for Titan . . . The Navy awarded Hughes Aircraft $\$7^1/_2$ million to build guidance systems for Polaris . . . Raytheon received $56.7 million more in Army funds for the Hawk program . . . Convair, $8.2 million more from the Army for continued development of Mauler . . . Martin-Orlando, $18.85 million from the Army for continued production of Lacrosse and its ground equipment . . . Aerojet-General, $2.5 million from the Navy for production of Tartar motors, and $3.6 million from the Army for continued development of the SD-2 surveillance drone . . . Thiokol, $2 million for the Corvus engine. . . . American Bosch Arma, $1.5 million for modifying fire-control systems and other work to accommodate the small Norwegian-designed Terne anti-submarine missile on U.S. Navy ships.

INTERNATIONAL

• Russia fired two multistage rockets into the Pacific on July 5 and 7, and then announced its latest series of tests of space hardware had been completed. U.S. Navy P2V Neptune patrol aircraft spotted both re-entry bodies as they arrived just after dawn by observing their vapor trails. The Navy fixed their range at 7700 statute miles, while the Russians claimed 8000 miles.

• The Russians have disclosed that their two previous Pacific shots (January 21 and February 1) were flight tests of the rocket booster which placed their "spacecraft" in orbit May 15. They have also indicated that the vehicles might be used in interplanetary shots. October this year is favorable for a Mars shot and January 1961 is the optimum time for a Venus attempt.

• The Russians also continue active on sounding-rocket experiments. Early in July they reported sending the dog Otvazhnaya ("Courageous") on his fifth successful rocket flight, 130 miles into the upper atmosphere, and announced plans to send the dog on another flight soon. The fifth Otvazhnaya flight also measured, according to the Russians, atmospheric ionization, the magnetic field, IR radiation of earth, and ultraviolet radiation of the sun, and as well took photographs of cloud cover "over a wide territory."

• Scientists of ten European countries—Sweden, Norway, Denmark, the Netherlands, Belgium, Great Britain, France, West Germany, Switzerland, and Italy—with the background of the COSPAR meeting in Nice last January, met in Paris recently, at the invitation of P. Auger, head of the French Commission for Space Research, to discuss a formula for pooling Europe's talents and resources in a joint space program.

• Meanwhile, the British Interplanetary Society continued to advocate strongly a British space research program, as described by the memorandum it submitted to the Prime Minister last March and a report it subsequently submitted to the Minister of Science. ♦♦

Over 25,000 informative cloud-cover pictures have been received from TIROS I since it was launched on April 1. In two months the satellite had completed 1000 orbits and travelled 27,500,000 statute miles. This means not only that TIROS itself has performed as planned, but that the complex problems of command and control, as well as signal reception and processing, have been successfully surmounted. Like the satellite, the special ground station equipments were designed and built by RCA Astro-Electronics Division under the auspices of NASA and technical direction of the U.S. Army Signal Corps.

Major components at each of the four ground stations include:

- Five TV receivers and four beacon receivers used in diversity reception to minimize signal fading
- A programmer which pre-programs different combinations of operating modes, and a 200 watt command transmitter
- A TV monitor to display the picture signal for the automatic recording camera. The camera is equipped to make either positive or negative films
- An indexer and sun angle computer which generate an index number and sun angle indication for each picture, used for geographical orientation
- An attitude recorder which picks up the earth-horizon signal for spin axis position computation
- Two standard 4-channel tape recorders to back up the monitor
- Two paper recorders to monitor forty telemetered satellite parameters
- An antenna programmer which directs the antenna to follow the orbit of the satellite when it is in range of the ground stations

All program functions are timed by a master clock which is synched to standard time signals from WWV. In addition to normal picture direct transmission and record functions, the programmer can also command spin-up. After two months the spin rate had decreased to 9.4 rpm's due to the effect of the earth's magnetic field. On command from the ground, two solid propellent spin-up rockets on the satellite were fired, increasing the spin to 12.8 rpm's.

AED's own ground station was used to process photos from the magnetic tapes for the first one hundred orbits.

The integrated design and development of these TIROS ground stations is an indication of AED's capability in *total satellite systems*. This capability will become increasingly critical as more and more complex satellites and space probes are launched to advance man's understanding and control of his universe. To discover how you can draw on this broad R & D experience, contact the Marketing Manager, RCA Astro-Electronics Division, Princeton, N. J.

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For the record

The month's news in review

June 6—Unusual segmented conical solid-rocket design wins United Technology Corp. an NASA contract for three demonstration engines. (See page 26.)

June 7—NASA announces contract over $500,000 to Hughes Aircraft for development of an experimental ion engine.

June 8—X-15's damaged when engine explodes in ground test.

June 10—Senate Appropriations Committee approves $84-million increase for Samos satellite.

—Hugh Dryden, NASA deputy director, says Pioneer V, in heliocentric orbit, "has overturned well-established theories about solar-flare effects and provided new information on the structure of the earth's magnetic field."

—Army reports Nike-Hercules downed a Corporal missile, first interception and kill of one guided missile by another.

June 11—AF successfully tests Arma inertial-guidance system for Atlas with 5000-mile shot.

—General Accounting Office report discloses NASA cancellation of Vega program last December to avoid duplication of similar work being done by AF with Atlas-Agena B has resulted in $16-million loss.

June 12—DOD says Project Banshee test, dynamite blast in stratosphere, will come off next Spring.

June 22—Navy launches piggyback satellite, Transit II-A.

—House Space Committee urges $13,800,000 three-year program for further research toward manned lunar expedition.

June 23—Army Signal Corps discloses a first—coast-to-coast radio conversation using 100-watt solar-battery-powered transmitter.

June 25—AF announces establishment of Aerospace Corp., nonprofit civilian agency, to manage some of the engineering and R&D phases of its space program previously handled by TRW's Space Technology Laboratories. Agency, at first, will take charge of Discoverer, Midas, and Samos satellite programs.

—Scientists plan 10-nation cooperative European space research center. Countries represented are Sweden, Norway, Denmark, Netherlands, Belgium, Britain, France, West Germany, Switzerland, and Italy.

June 29—Soviets announce new series of long-range missile firings in Central Pacific will be held between July 5-31.

—NASA discloses Tiros I has stopped sending cloud-cover pictures. Since its launching April 1, satellite has sent back some 22,952 pictures.

Mail bag

More on Covers

Dear Sir:

The cover of the June 1959 *Astronautics* has been brought to my attention by a fellow colleague and a member of your Society (Dr. Jim Miller #426 originally). The cover is quite striking and both you and the artist are to be complimented; he for the drawing and you for seeing the value as a cover.

The California Optometric Association has recently formed a new state committee known as the "Space Vision Committee." Since I believe this committee will be quite active in the future, I am anticipating the receipt of copy from the committee and the possible use of a startling cover, such as you used.

I would appreciate permission to reprint your cover giving appropriate credit to the author and Society. I would also appreciate a copy of the June 1959 issue if it is possible to obtain same.

Thanking you in advance for any courtesy you may extend, I am

HERBERT KALLMANN,
O.D. Editor
Journal of the COA

To Be Specific (Contd.)

Sirs:

Mr. S. W. Greenwood of the British Interplanetary Council proposes in your June Mail Bag that the units of specific impulse be standardized as pounds (force) seconds per pound (mass), and that this be abbreviated "Lb secs/lb." He admits, however, "the chance that [any rocket engineer] will cross out the pounds on top and bottom without considering what they are is horrifyingly high."

Fortunately, however, there exists in the United States a recognized standard that may restrain our rocket engineer a bit more from crossing out dissimilar units. This is MIL-STD-292A (Feb. 10, 1958), "Military Standard—Ballistic Nomenclature—Rocket Static Tests." It was adopted by the U.S. Department of Defense following recommendations of the Joint Army-Navy-Air Force Solid-Propellant Rocket Static Test Panel, which contains representatives of most important industrial and governmental agencies active in solid-propellant rocket static testing. A revision (MIL-STD-292B) is being issued, but no change has been made in specific impulse nomenclature. In this Standard, specific impulse is again expressed as pounds (force) seconds per pound (mass), but is abbreviated "lbf-sec/lbm." This nomenclature clearly indicates that force and mass are different things, and should not be cancelled against each other.

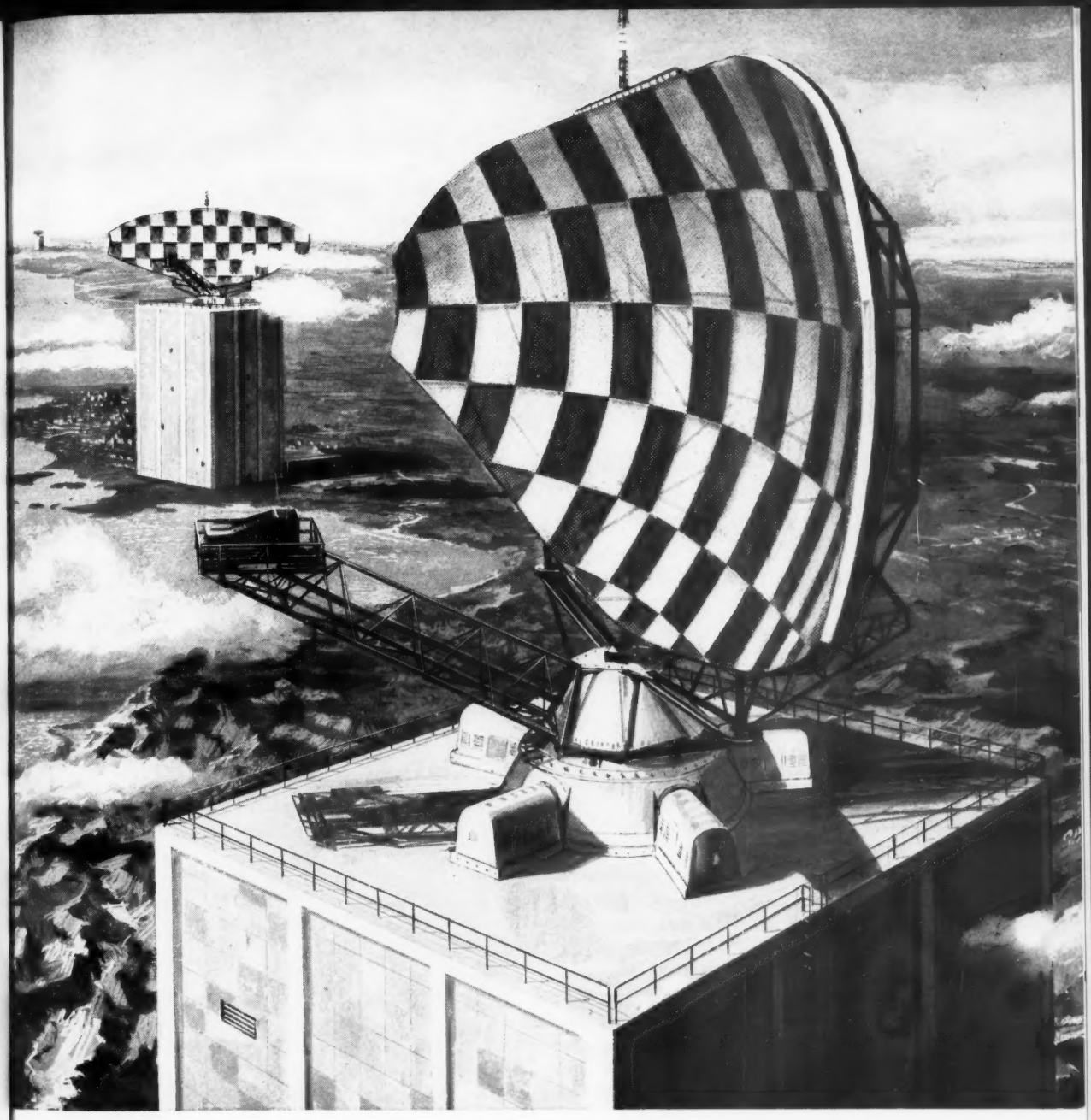
Since we have a standard that is clear and that has been recommended by the Department of Defense and by a representative group of solid propellant engineers after careful study, why don't we agree to use it?

DANIEL L. BABCOCK
Solid Propellant Information Agency
Applied Physics Laboratory
Johns Hopkins University
(representative to the Joint
Army-Navy-Air Force Solid
Propellant Rocket Static Test Panel)

Gentlemen:

The paper on "One-O'Clock Propulsion Systems" in the April 1960 issue of *Astronautics* was cleverly put, and I rejoice at the effort to clarify the muddle on units and dimensions of specific impulse.

(CONTINUED ON PAGE 88)



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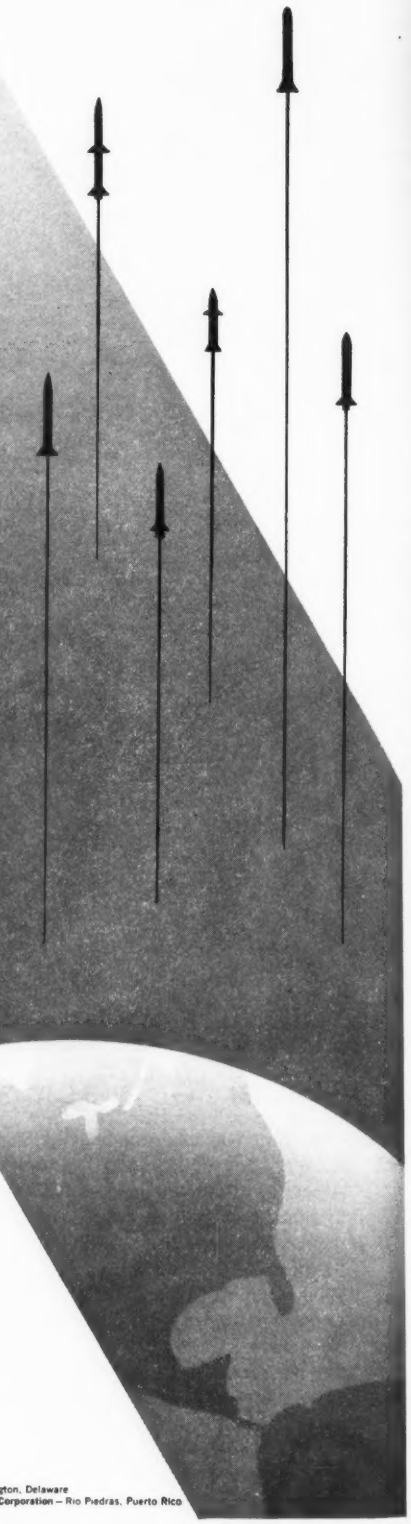

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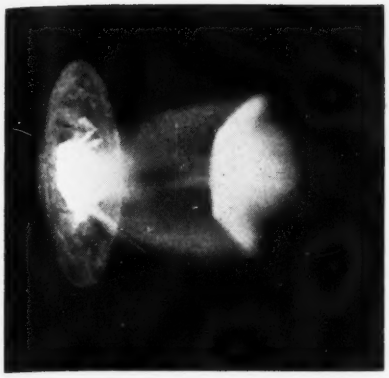


COVER: *Glowing plasma from a small solid-propellant generator, under study for space application by GE's Space Sciences Laboratory, suggests the potential of magnetohydrodynamic power generation (see page 22). This test run was one of a series made by the Laboratory in May at the GE Malta Test Station. (Full-color ASTRO cover plaques, 11 x 12 in., are available from ARS Headquarters at $2.00 each.)*

Astronautics

AUGUST 1960

Group Ego

Webster defines one meaning of ego as "the self-assertive and self-preserving tendency." In this sense, most groups, whether they be families, schools, corporations, or professional societies, possess an ego. Yet the group itself is an abstraction. No particular journal, person, or office constitutes the group. To each individual member, the group is simply the sum of his personal associations and impressions, and his loyalty to it a conditioned response to repeated stimuli.

Why point this out? Because swiftly advancing technology is changing the character of existing major professional groups, including ARS, and causing them to resemble one another closely. When founded, each group encompassed clear-cut and unique fields of subject matter. Now, each may share more than half its interests with others. An inevitable consequence of this situation is that such groups must either compete or cooperate. They are both interested in the same members, technical papers, and advertisers.

What action does this trend require? If the societies are not to deteriorate into a number of relatively feeble sectarian competitors, jealous of each other, they must remain receptive to information concerning fellow engineering groups. We tend to fear what we do not understand (and sometimes of course, what we *do* understand!). I would urge special effort to communicate among the groups. The sharing of local meetings, the joint or duplicate publications of select technical matter, conferences between the leaders, all would help build mutual understanding and good will.

It is not practical for human beings suddenly to dislocate their group identity, vested interests, and family pride. The establishment of a new set of favorable conditioned responses toward a larger and nobler group takes time and must be accomplished carefully and deliberately. There are ample technical fields to keep everyone busy, with new ones continually developing. We should take care then, as a group, not to be too rigidly egoistic, but to remain adaptable.

Howard S. Seifert
President, AMERICAN ROCKET SOCIETY

The prospects of MHD power generation

Major applications, other than a short duty cycle generator for space vehicles, await answers to major questions about magnetohydrodynamic phenomena, and the advent of fruitful inventions

By Leo Steg and George W. Sutton

GE SPACE SCIENCES LABORATORY, MSVD, PHILADELPHIA, PENN.

Steg Sutton

Leo Steg studied at City College of New York and the Univ. of Missouri and received a Ph.D. in applied mechanics, mathematics, and physics at Cornell Univ. Dr. Steg was an assistant professor of applied mechanics at Cornell for seven years and a consultant for several organizations before joining GE's Missile and Space Vehicle Dept. in 1955. The Space Sciences Laboratory, which he directs, conducts research in environmental phenomena, dynamical astronomy, and plasma physics. Work in this last field resulted in the first public announcement of MHD-generated power in October 1959.

George W. Sutton received a Ph.D. Magna Cum Laude from the California Institute of Technology in mechanical engineering and physics. Since coming to the Space Sciences Laboratory in 1956, Dr. Sutton has done pioneering research on ablation for missile and satellite applications. For the past two years, he has been investigating the application of magnetogasdynamics to electrical energy conversion. Dr. Sutton recently was appointed a lecturer in magnetohydrodynamics at the Towne School, Univ. of Pennsylvania.

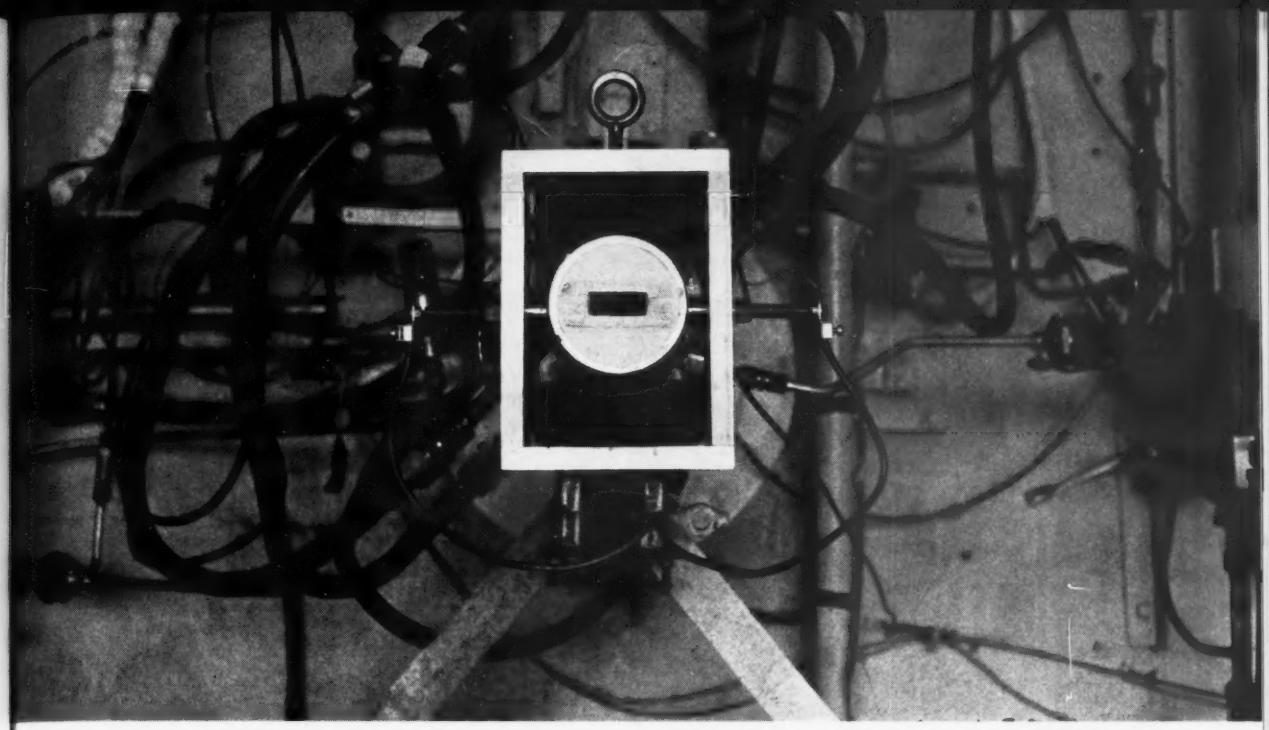
WE CAN begin by addressing ourselves to history. The generation of electric power by passing a conducting fluid through a magnetic field is not a new concept. It is based on a well-known principle, which states that a conductor cutting magnetic lines of flux generates an electromotive force.[1] The use of liquid conduction—for example, in the induction flowmeter and in electromagnetic pumps—is a well-established technology.

But there is now a new word—magnetohydrodynamics (MHD)—to witness a contemporary interest in ionized gas as a working fluid. The gaseous MHD generator in principle appears at first glance to have some outstanding advantages over the conventional turbogenerator. In the latter, steam energy is first converted into mechanical energy (in the turbine) and then into electrical energy. The working fluid in the MHD generator also acts as the conductor, thus affording a basically simpler concept. Moreover, the relatively higher temperatures at which the MHD converter must and, in the absence of dynamical mechanical stresses, should be able to operate raise the possibility of an increase in the over-all thermal efficiency. Finally, the MHD concept may be attractive from a systems point of view in both stationary and auxiliary power applications.

The basic attraction for stationary generation lies in the potential in thermal efficiency available from fuller utilization of the high temperatures attainable in the combustion process. Typically, in a combined open turbine cycle, the combustion gases (properly seeded) enter the MHD converter, which extracts power from the flow, resulting in a reduction in enthalpy. The gas is then utilized to preheat the combustion mixture, and this results in a further drop in temperature, to a level suitable for conventional boiler operation. One would expect, therefore, an increase in over-all efficiency as a bonus.

For auxiliary power units, the principle would seem attractive initially for short duty cycles, where the source of high-temperature working fluid might be a rocket exhaust or the ionized gas in the flow field surrounding a hypersonic vehicle.

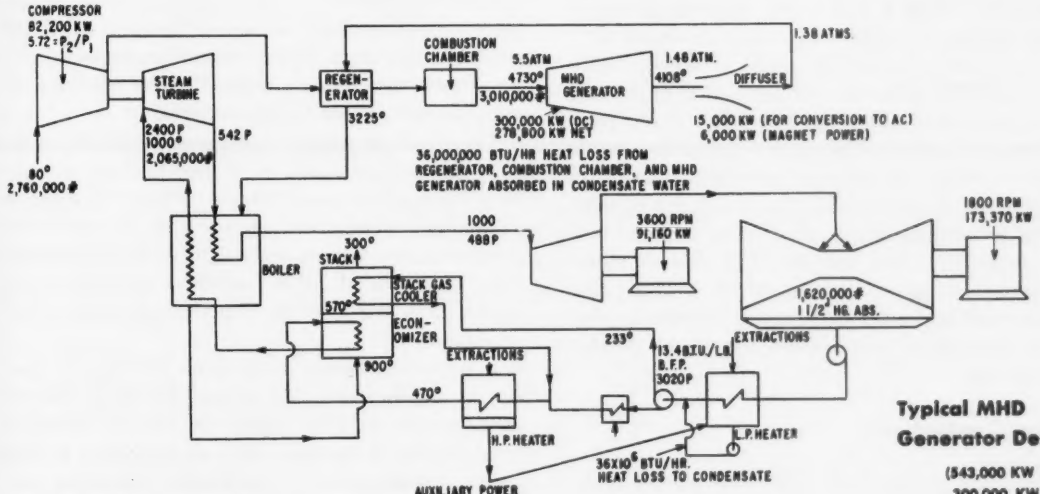
Some important characteristics of gaseous conductors may be



The prospects for MHD power generation range from the small, short-duty-cycle unit rated at 1 to 100 kw for space applications to the large power station rated at hundreds of thousands of kilowatts for commercial use. The first is an experimental reality, like the GE liquid-rocket-fed unit shown above head on, so that you see the exhaust slot and flanking magnets, mounted for a firing at the GE Malta Test Station. Below, a diagrammatic analysis of a large power station, prepared by R. C. Sheldon of GE, which theoretically gains a 16.2 per cent improvement in performance over a conventional station by the presence of an MHD generator.

MHD Generator Topping Steam Unit

(PRELIMINARY CONCEPTUAL OPEN-CYCLE DESIGN)



MHD GENERATOR OUTPUT	278,800 KW
STEAM TURBINE OUTPUT	264,530 KW
TOTAL TERMINAL OUTPUT	543,330 KW
AUXILIARY POWER	20,100 KW
NET STATION OUTPUT	523,230 KW

AUXILIARY POWER

BOILER FEED PUMP	8140
CIRCULATING WATER PUMP	2190
MISCELLANEOUS AUX. POWER	4720
MISCELLANEOUS BOILER LOSSES	1030
SOOT BLOWERS	1030
PULVERIZERS	2010
	191207.95=20,100 KW

NET HEAT RATE (INCLUDING AUXILIARIES) = 6687 BTU/KW HR.

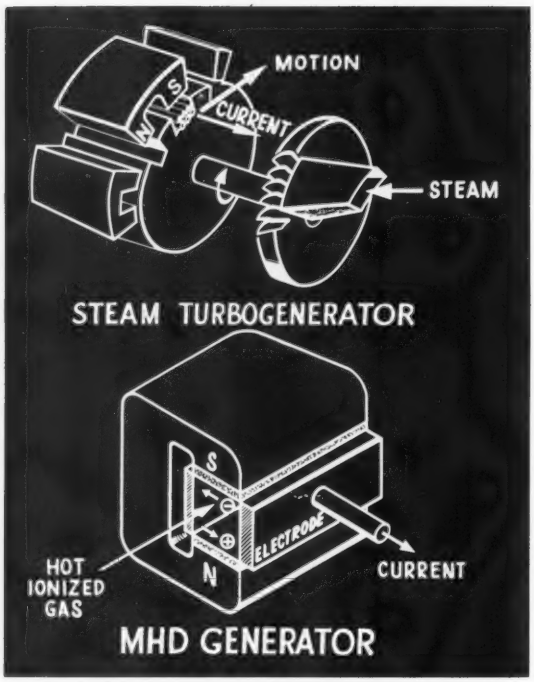
NET HEAT RATE OF CONVENTIONAL 2400P/1000/1000°/1 1/2" UNIT (INCLUDING AUXILIARIES) = 7982 BTU/KW HR.
IMPROVEMENT DUE TO MHD GENERATOR = 16.2%.

Typical MHD Generator Design

(543,000 KW TOTAL OUTPUT; 300,000 KW MHD OUTPUT)

Inlet total pressure	5.5 atm
Inlet total temperature	4730 F
Magnetic field strength	20,000 gauss
Gas flow	3,010,000 lb hr
Gas velocity	2400 ft sec
Length	85 ft
Terminal voltage	4000 volts
Width between electrodes	11.2 ft
Height at entrance	1.0 ft
Height at exit	3.3 ft
Exhaust total temperature	4120 F
Preheat air temperature	2311 F
Power for exciting magnet	6200 kw
Weight of steel in magnet	12,000 tons
Weight of copper in magnet	600 tons
Seeding material injection and recovery	30,000 lb hr

Steam and MHD Generators Compared



noted by comparing them with metallic conductors. The electrical properties of ionized gases differ from metallic conductors in at least three important aspects. First, ionized gases are not ordinarily good conductors; at 3000 K and 3 atm, air seeded with 1 per cent molar potassium has a conductivity of 10^{-6} that of copper. This would imply an internal volume of an MHD generator 10^6 times that of copper in a copperwound alternator operating at comparable linear velocities. This factor can be decreased perhaps to 10^3 by the high gas velocities possible.

Second, the MHD generator must utilize basically different techniques to pass the current into and out of the generator. And last, the Hall effect is more predominant in gases than in metals. Thus, the generator can no longer have simple homopolar design; it requires a considerable degree of design sophistication.

Gaseous Conductivity

Combustion gases must usually be seeded with additives of low ionization potential (e.g., cesium or potassium) to obtain sufficiently high values of electrical conductivity.[4] The question of the electrical conductivity of a partially ionized gas then becomes an important consideration.

This depends upon the degree of ionization and the elastic electron-scattering cross section.[2] At present, the number density of electrons in a gas is calculated by means of the Saha equation, which is based upon thermodynamic and chemical equilibrium between electrons, molecules or atoms, and ions. In the case of electron densities of the order of 10^{15} per cc, this theory needs extensive modification, for two reasons. First, each ion is surrounded by a cloud of electrons that tends to reduce its electric field and therefore its chemical activity. A theory to include this effect has recently been proposed.[19] Second, the presence of an electric field within the gas affects equilibrium conditions, due to the difference in ion and atom polarizability. But, perhaps more important, the presence of the electric fields of the magnitude required by an MHD generator causes the electron temperature to be somewhat higher than the temperature of the surrounding gas.[2]

Thus, the system is unlikely to be in thermodynamic equilibrium, and the Saha equation may not be applicable. To properly calculate the degree of ionization, the ionization and de-ionization processes and, in particular, specific reaction rates will probably have to be known in some detail. This requires refined experiments. Quantum-mechanical calculations may yield some meaningful results, although the presence of impurities in the MHD generator will complicate the situation.

The electron-scattering cross section of neutral atoms and molecules is not well known. Experimentally, it is usually obtained in Ramsauer-type experiments.[3] Approximate quantum-mechanical calculations have also been made. Some of the more recent involved the use of the Thomas-Fermi model of the atom, which should be applicable for atoms of large atomic number.[17] The results, however, do not appear to be encouraging.

The graph on page 84 compares the results of the Ramsauer experiments to Fermi-Thomas calculations for mercury and thallium. Clearly, further investigation is required. In addition, Ramsauer experiments are usually limited to electron temperatures in excess of 10^4 K, which is probably much higher than will ever be experienced in an MHD generator.

It is next necessary to combine the number density of electrons and the neutral particle-scattering cross section into an expression for the electrical conductivity of the gas. For very slightly ionized gases, a rigorous theory is available;[2] and for a completely ionized gas, several theories have been developed which are in agreement with each other.[6] For a partially ionized gas, however, the available theories are less descriptive, especially if the electron temperature exceeds the gas temperature.[7]

Experimental verification of electrical conductivities is also difficult. At electron densities of 10^{15} electrons per cc, it is not possible to use microwave

diagnostics, because of the attention of such waves at frequencies below the plasma frequency. Observation along magnetic lines of flux using the Whistler mode of propagation in an ionized medium has been suggested. This is not, however, an easy experiment.

In the MHD power experiments run to date,[13,15,18] the over-all conductivity of the gas, as deduced from the current-voltage relationship obtained during the experiment, does not agree with simple equilibrium theory. With air as a working fluid, the agreement was within 10 per cent, which would indicate that at a temperature of 5000 K the average electron-scattering cross section is about 10^{-15} cm^2. The experiments which used argon seeded with potassium showed considerably larger divergence. More-refined nonequilibrium investigations are therefore of considerable interest, particularly since there is some indication that the existence of nonequilibrium may result in an improved performance.[3]

Electron Emission

The method of extracting the electrical current illustrates another important difference between a gaseous and a metallic conductor. In the usual alternator, which uses metallic conductors, this is accomplished simply by (CONTINUED ON PAGE 82)

Comparison of Exploratory MHD Generator Experiments

Characteristic	Foshag and Were[13]	Rosa[15]	Way[18]
Gas	Air and Carbon	Argon	Flue
Total Temperature	5500 K	3260 K	3030 K
Static Temperature	5000 K	2800 K	2840 K
Wall Temperature	.....	.....	2975 K
Pressure	5.5 atm abs	12–20 psig	2 psig
Mass Flow	1 lb/sec	0.67 lb/sec	1.1 lb/sec
Velocity	1350 M/sec	688 M/sec	820 M/sec
Mach No.	1	0.7	0.8
Seeding Material	1% K	1% K_2CO_3	2% molar K
Generator Dimensions	$^3/_8 \times 2 \times 2$ in.	$1 \times 3 \times 20$ in.	$1^5/_8 \times 4^7/_8 \times 16$ in.
Test Duration	9 sec	5 sec	4 min
Electrode Material	Graphite	.....	Graphite
Insulator Material	Silica	.....	Zirconia
Magnetic Field	8600 Gauss	14,000 Gauss	14,000 Gauss
Open-Circuit Voltage	31 v	55 v	43 v
Short-Circuit Current (est)	150 amp	800 amp	370 amp
Power Density	63 w/cm^3	20 w/cm^3	3 w/cm^3
Electrical Conductivity	350 Mho/M	65 Mho/M	47.5 Mho/M

Facilities for MHD Research

Characteristic	2500 kw Carbon Arc	Rocket Exhaust	Low-Density Arc-Wind Tunnel	Small Plasma Jet	Heated Wind Tunnel	Shock-Tube/ Tunnel
Temp, K	3000–5000	3300	2600	3000–5000	2000	3–7000
Velocity, fps	0–5000	0–7000	15,000	3000	*	*
Pressure	1–10 atm	20 atm	0.01 to 0.001 atm	8 atm	*	*
Channel Width	10 cm	30 cm	20 cm	0.5 cm	20 cm	15 cm
Generated Voltage	60	300	600	5	*	*
Conductivity mho/cm (based on 1% seed)	1 to 4	0.1–0.7	4	4	0.04 at 1 atm	*
Channel Length, cm	60	60	60	5	*	60
Test Time, sec	20	30	120	60	*	0.001
Power Generated, kw	50	10	Hall effect	0.001	5	*
Hall Effect ($\omega_e\tau_e$)	0.25	0.25	25	0.25	small	*
Electron Emission from Electrode	easy	easy	difficult	easy	difficult	difficult
Pressure Drop	1 atm	0.1 atm	10^{-4} atm	0.06 atm	..	?
Effects on Materials	severe	severe	light	severe	light	very light
($\sigma B_0^2 Lu/\rho_0 u_0^2$) max** B_0 = 10,000 gauss	0.4	0.035	2×10^3	0.04	10^{-2}	*

* Varies over Wide Range.

** Magnetic Interaction Parameter–(Ponderomotive Force/Momentum).

A space shape for solids

Segmented conical rockets, to be evaluated in the coming year for NASA, promise versatile performance and economy for space missions

Anthony C. Keathley, head of the UTC Solid Rocket Project Dept., has 12 years of experience in the field of rocket ballistics and propulsion. After receiving a B.S. in physics from New Mexico State College, he joined Phillips Petroleum's Rocket Fuels Div., later renamed Astrodyne, Inc., there becoming supervisor of rocket design and project engineer in charge of all phases of design, process, assembly, and testing of large rocket motors, and later technical staff assistant to the director of engineering and development. He was responsible for the direction of studies which led to advanced designs associated with lightweight case and nozzle construction, propellant processes, assembly, and solid-propellant motor tests. Keathley has six patents pending in the U.S. and abroad on solid-rocket components.

By Anthony C. Keathley

UNITED TECHNOLOGY CORP., SUNNYVALE, CALIF.

THE NATIONAL Aeronautics and Space Administration recently awarded a contract to United Technology Corp. to demonstrate the feasibility of a segmented cone-shaped solid rocket. The several unique features of this rocket taken together represent a revitalizing concept in the design and development of solids, particularly for large vehicles. We believe this concept solves in one stroke a host of problems historically associated with big solid rockets, and gives the solids sound grounds for competing with liquids in space boosters.

What does the concept entail? First, segmentation of the grain. Other groups have also advanced this approach, and understandably so. You would be unhappy if you poured a single grain weighing a few hundreds of tons and then discovered a crack in it. You would be even more unhappy if you then had to dispose of the grain safely. These are just two of a number of problems associated with forming large unitary grains by continuous pouring operations at the launching site, a procedure that has been proposed.

On the other hand, if you can build a grain in segments, you can work with a limited amount of propellant under controlled conditions, in a plant expressly designed for propellant manufacture and motor loading. You can store the segments in safe magazines and inspect them carefully when necessary. You can reject a faulty segment without sacrificing a whole rocket motor, and you can replace a segment quickly and with ease.

Moreover, segments can be designed to meet the exigencies of practical handling equipment and transportation facilities. For ex-

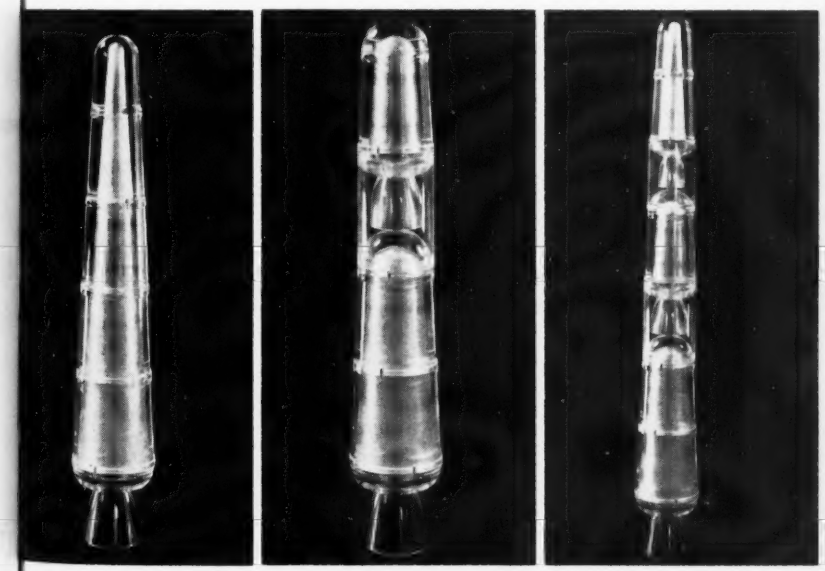
ample, we see no major obstacle to building segments about 10 ft in diam and 10 ft long. These would weigh no more than 60 tons, including the combination handling and carrying trailer, and could be transported over our present highways or railroads.

Manufacturing a large solid-propellant rocket motor in the form of building blocks, then, bases operations on an established technology, efficient and economical. In conjunction with the cone shape, the segmented grain offers other major advantages in the areas of design and development, of which more in a moment.

The second part of the concept, the cone shape, may be thought of as latent in solid-propellant rocket design technology, appearing new because it has not been seen with such conscious clarity in the past. For instance, many high-performance solid-propellant rockets employ a grain with a tapered perforation to increase volumetric loading without incurring excessive erosive burning. The cone shape includes these objectives, and attains them with much simpler form.

At this point, a glance at the photos shown of the design proposed will be helpful. The grain can be seen as cone-shaped with a rounded apex. It is a plain internal-burning grain, centrally perforated in simple conical form, with the walls of a uniform thickness, and bonded to the motor case. The hole, or port, through the grain obviously gets larger going from the head to nozzle end.

This simple fact helps greatly to solve a quandary in good solid rocket design—balancing the usually conflicting demands for initial high volumetric loading and final low residue of propellant (slivers) against the need for a satisfactory pressure- (CONTINUED ON PAGE 38)



These models show the concept of the segmented conical motor. From left to right, a single propulsion unit, a two-stage booster, and a three-stage booster, such as might be used for launching satellites. The conical segments making up such vehicles would constitute a kind of do-it-yourself kit of rocket motors for space missions—as the author says, any mission off the shelf!

1961 SPACE FLIGHT REPORT TO

85 per cent of space on second floor of New York Coliseum already reserved for ARS 1961 meeting . . . 300 companies to exhibit, 300 papers to be given . . . Professional attendance of 10,000 anticipated

By Roderick Hohl
ARS MEETINGS MANAGER

THE ARS SPACE FLIGHT REPORT TO THE NATION is off to a flying start, with exhibit reservations on the main floor of the New York City Coliseum, where the show is to be held, already accounting for almost double the total amount of space rented at any of the Society's previous meetings.

To be held during the week of October 9–13, 1961, the SPACE FLIGHT REPORT TO THE NATION will be the largest meeting devoted solely to astronautics ever held. There will be three full floors of exhibits and six simultaneous technical sessions daily, with more than 300 papers presented during the five-day meeting.

The meeting has a threefold purpose, in that it is aimed at the scientists and engineers working in the field, at the manufacturer, and at the public. Howard S. Seifert, ARS national president, in summarizing the meeting's objectives, pointed out that it will provide the professional with a complete review of the field through technical papers and demonstrations and displays of current hardware; it will give companies in the field an opportunity to display their latest developments and products; and it will acquaint the general public

OBJECTIVES OF THE ARS SPACE FLIGHT REPORT TO THE NATION

October 9–13, 1961, New York Coliseum

(1) To provide engineers and scientists in the rocket, missile, and space-flight fields with a review, through technical papers and reports and demonstrations and actual exhibits of hardware, of the nation's current status in this field, and to point the way to further and faster progress;

(2) To give designers, manufacturers, and suppliers a prime opportunity to show and demonstrate the concepts, plans, and products they have to offer for the more rapid progress of the country's astronautics program, and

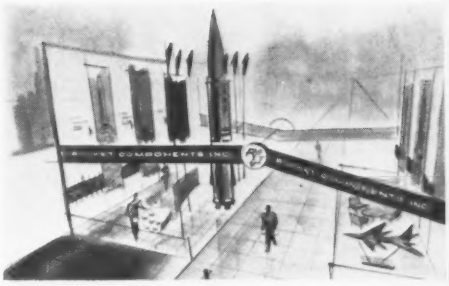
(3) To acquaint the general public, through the press, television, radio, and by special lectures, exhibits and demonstrations, with the actual status of our national effort to conquer space, the concepts and objectives of the Space Age, the plans and programs that may be expected to produce successful accomplishment in the near and more distant future, and above all, the importance of rockets, missiles, and space flight to every American, with a view to enlisting and maintaining more active public understanding and support for this rapidly growing program.

THE NATION off to flying start

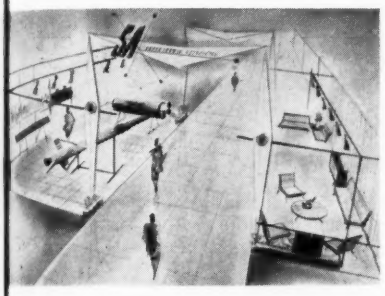
with the concepts and objectives of the Space Age in an effort to further public understanding and support.

No general campaign has as yet been initiated to sell exhibit space at the meeting, but Lawrence Craner Jr., ARS exposition manager, reports that reservations have already been made for 85 per cent of the space on the Coliseum's second floor following the release of floor plans to corporate members and exhibitors at previous ARS shows.

All booths on this floor with the exception of those along the walls will be of the island type, the focal point being an 88 x 50-ft National Aeronautics and Space Administration exhibit. Plans for the NASA display are already on the drawing boards and are expected to be made public at the end of this year.

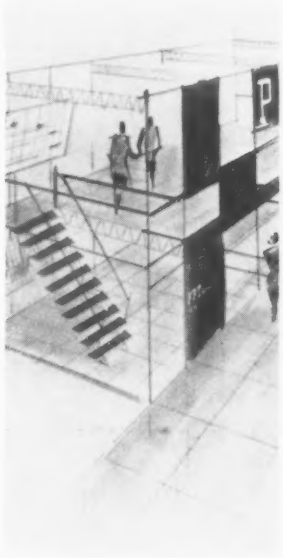


ARS planned the SPACE FLIGHT REPORT TO THE NATION more than a year ago to meet the increasing demand for additional technical sessions and exhibit space at annual meetings. At recent meetings, it was necessary to turn away prospective exhibitors and cut down requests made for technical sessions by technical committees.



To correct this situation, the ARS Board of Directors voted to take bold action and move the Society's annual meeting from its usual hotel location to the New York Coliseum in 1961 and present to the nation the first full-scale report on all phases of astronautics.

While the meeting will be held in larger quarters, the dignity that has marked past ARS meetings will be maintained. All technical sessions will be held on the fourth floor of the Coliseum in six specially constructed, soundproof rooms. All hallways on this floor will be carpeted and special lounge areas will be constructed so that the 10,000 professional attendees expected will not be deprived of the opportunity to hold the valuable informal discussions which have marked previous ARS meetings. An art exhibit, including works by some of the country's top artists on space themes, will warm the usually bleak walls.



The lower three floors of the Coliseum will be devoted to the exposition proper, with some 300 companies expected to exhibit their wares in 220,000 sq ft of space. To insure that these displays have maximum impact, ARS is instituting a new concept in exhibiting which has already aroused the interest of professionals in the field.

Developed by Robert T. Kenworthy, Inc., the Society's exposition management firm, this concept, called "Exhibiting in Depth," provides exhibitors with booths which include space on both sides of an aisle. Exhibitors will be permitted to bridge aisles with company signs and tie the two sides of their booths together with carpeting or colored tiles if they so desire.

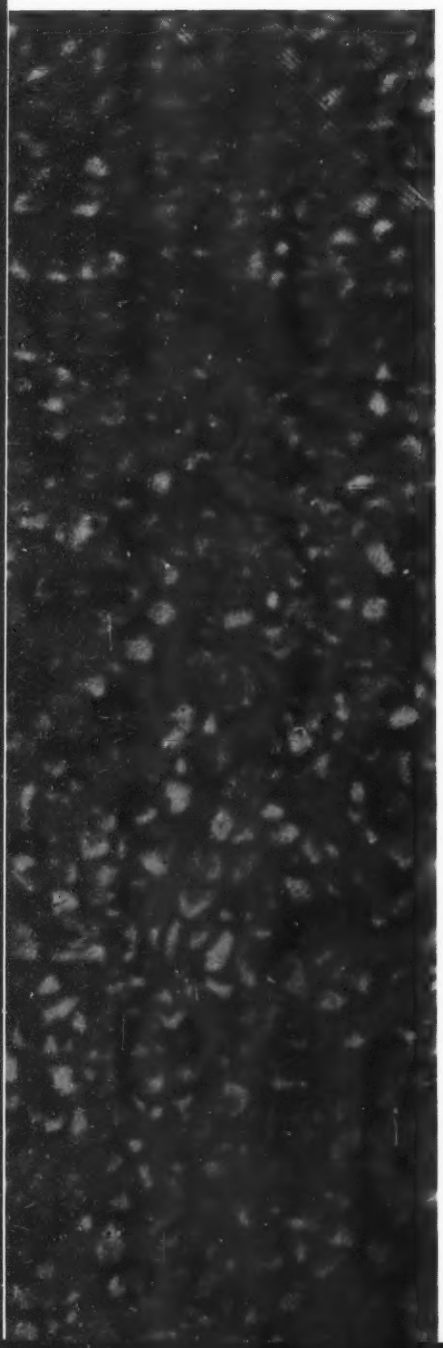
Each exhibitor is being allowed a good deal of leeway in preparing his exhibit so that he may use every means available to him in telling his company story without interfering with the exhibitor in the adjoining booth. Even two-story booths will be permissible—the first time such exhibits will be found in a major American exposition.

The "Exhibiting in Depth" principle will be employed on the first and third floors of the Coliseum, as well as for the regular space on the second floor. (CONTINUED ON PAGE 77)

ASTRONAUTICS Report—Part 4

Observation satellites: Problems and prospects

Operating above the earth's atmosphere, satellites of this type can make many contributions to astronomy, astrophysics, and various earth sciences, and also provide us with an extremely accurate map of earth



By Amrom H. Katz

THE RAND CORP., SANTA MONICA, CALIF.

THE REPORT, "Introduction to Outer Space," prepared by the President's Science Advisory Committee, noted that a satellite in orbit can do three things:

1. It can sample the strange new environment through which it moves.

2. It can look down and see the earth as it has never been seen before.

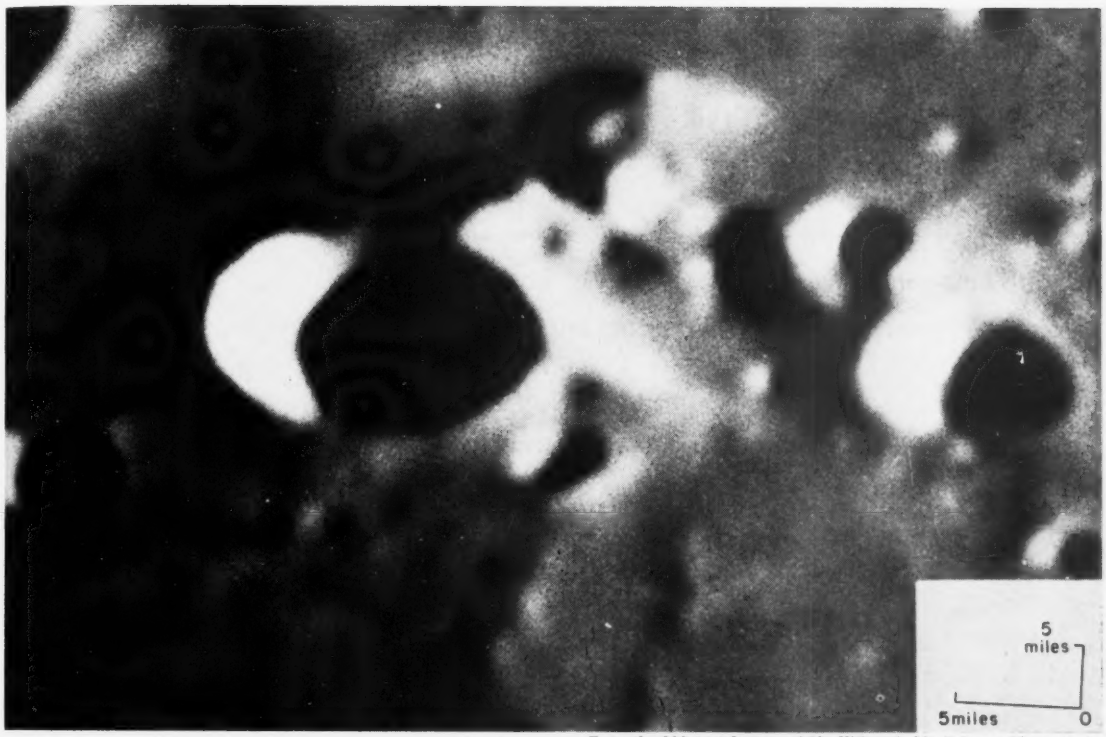
3. It can look outward and record information that can never reach the earth because of the intervening atmosphere.

In addition (as noted in a subsequent section of this series), a satellite may be used as a high-altitude beacon, which, when photographed from several widely separated ground stations, may help make more accurate distance measurements between continents.

This section will discuss briefly those particular scientific and technical uses which fall into the third category and can be served by observation satellites carrying photographic-type instrumentation. (Such other uses as observation, inspection, meteorological observation, and mapping are all discussed elsewhere in this series.) Specifically, this means the photography and observation of other celestial objects. ("Celestial objects" of possible observational interest may eventually include observation and inspection of other man-made satellites, and of space stations, but these will not be considered here.) The moon and the earth's sister planets of the solar system can be seen and studied from satellite platforms without the image-degrading effects of the earth's atmosphere.

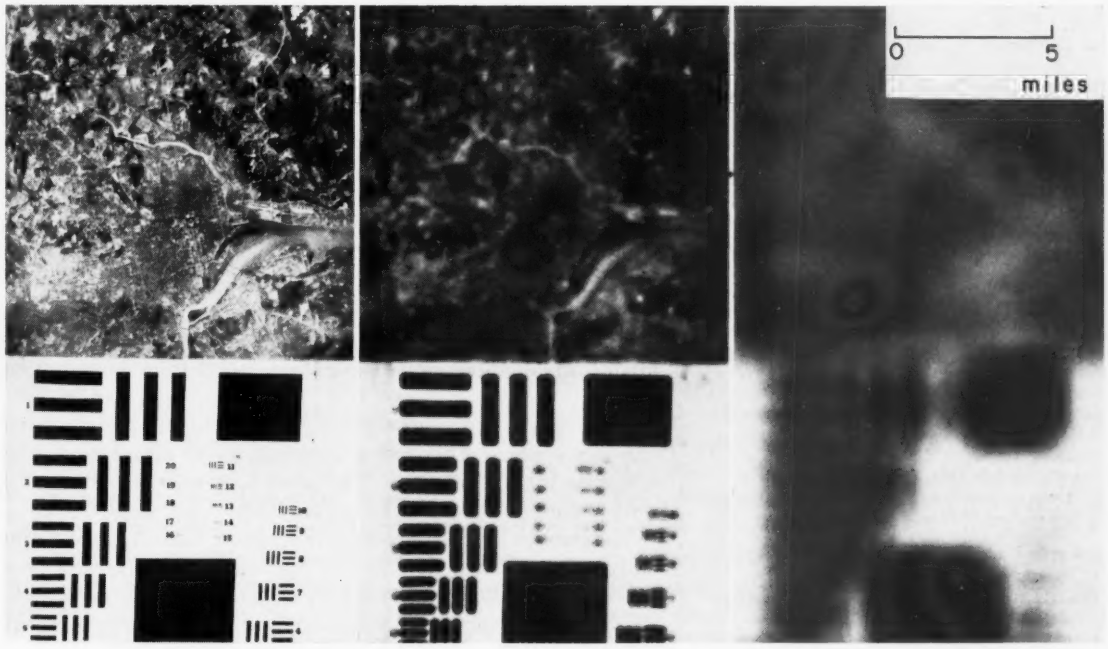
Astronomers who have patiently awaited for the infrequent occurrence of good "seeing" know full well the trouble and limitations imposed by the atmosphere. Three categories of effects which prevent the realization of the theoretical resolution capabilities of large telescopes are lumped together under the general term "seeing." First, there is motion of the image, or (CONTINUED ON PAGE 59)

A portion of the solar surface, shown in an enlargement of the best frame, from the standpoint of resolution, secured by the balloon-borne telescope in Project Stratoscope. Resolution is about the theoretical limit of the 12-in. aperture telescope used—roughly $^1/_3$ sec of arc.



From the 200-in. telescope of Mt. Wilson & Mt. Palomar Observatories

Photography of the moon (above) and Washington, D.C., (below) at the same scale, demonstrate that aerial photography of the earth at a ground resolution corresponding to the best lunar photography is extremely poor.



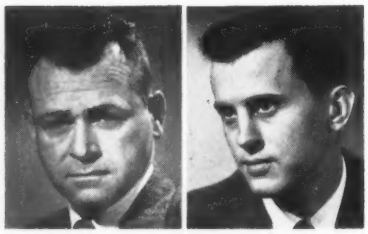
200-Ft Ground Resolution | **1000-Ft Ground Resolution** | **5000-Ft Ground Resolution**

Progress report on Project Mercury

Reviewed in the light of two-years' experience, the nation's man-in-space project shows both stability of aim and approach and a maturing engineering form

By Charles J. Donlan and Jack C. Heberlig

NASA SPACE TASK GROUP, LANGLEY RESEARCH CENTER, LANGLEY FIELD, VA.



Donlan Heberlig

Charles J. Donlan was assigned to the NASA Space Task Group on its formation in October 1958, and was appointed to his present position, assistant director of Project Mercury, in February 1959. Prior to his appointment to the Space Task Group, Donlan was technical assistant to the associate director of the Langley Research Center, where he helped initiate, guide, and direct research in various fields, especially aerodynamics, stability and control, and hydrodynamics.

Jack C. Heberlig is technical assistant, Office of Project Director, NASA Space Task Group, and was previously a Mercury-Redstone project engineer in the Space Task Group Flight Systems Div. Before being assigned to the Space Task Group when it was formed in October 1958, Heberlig was with the NASA Langley Research Center's Pilotless Aircraft Research Div., where he was active in basic research for manned space vehicles during 1957 and 1958.

Presented at the Psychological Aspects of Space Flight Symposium, sponsored by the AF School of Aviation Medicine and arranged by the Southwest Research Institute, this paper will also appear in a Proceedings to be published by the Columbia Univ. Press.

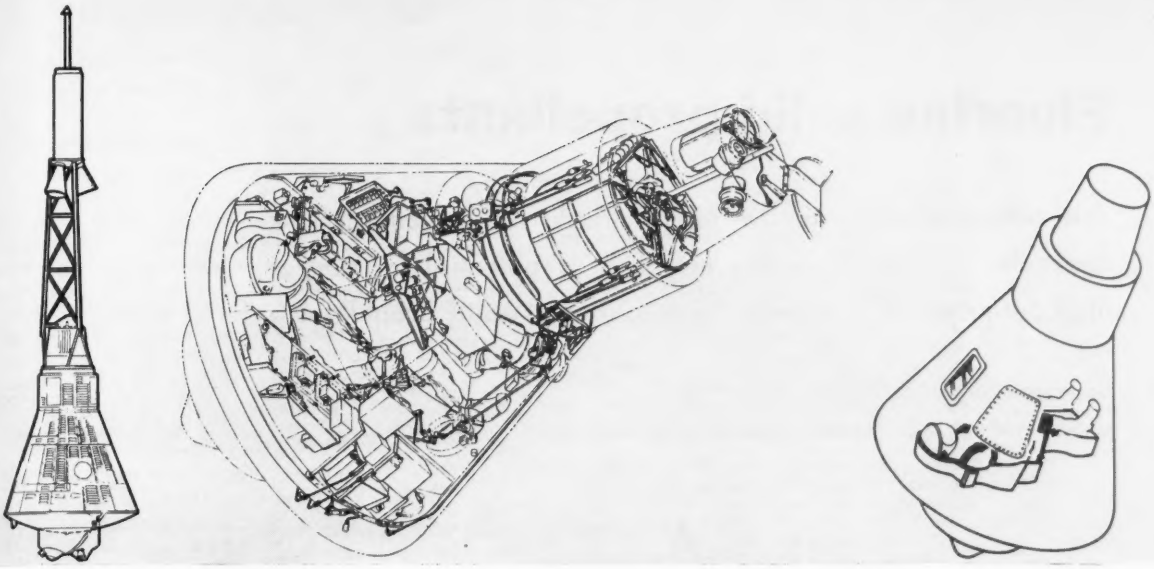
PROJECT Mercury, our country's program for manned orbital space flight, enters the more dramatic stages of flight testing this fall. With major flights in the offing, we would like to review Mercury concepts and hardware in the light of our development experience thus far.

The original aims and concepts for Project Mercury, announced when it received official status Oct. 5, 1958, still guide the program. The main aims of Project Mercury are to orbit and recover a man in a space capsule safely and to study man's capabilities in space. The Mercury concept calls for simplicity and reliability, a minimum of new developments, and a progressive build-up of tests to demonstrate reliability. The basic engineering approach has been a drag vehicle boosted by an available ICBM propulsion unit; retrorocket start of descent from orbit; parachute braking of the final phase of re-entry; and an escape system for the launching and early-flight phases. The present state of space-vehicle technology indicates that the decision to base work on a high-drag shape for ballistic re-entry was a wise one.

The illustration on page 33 shows the Project Mercury capsule with its escape system. The capsule has a maximum diameter of approximately 74 in. With escape rig, it is about 25 ft high. The heat shield is an ablating phenolic resin. There are three rockets in the retro unit, mounted on the heat shield. The capsule's afterbody has a sheath of cobalt-alloy shingles that can expand in all directions to minimize stress from high heating rates.

The cylinder atop the capsule proper contains the parachute recovery system. This system continues to be tested extensively to insure high reliability. The capsule, moreover, will have a reserve chute to back up the primary one.

The escape rig, tripod-mounted above the capsule during launch, can remove the capsule from the booster at any time. Tests of this system simulating an off-the-pad abort, an abort at maximum dynamic pressure on exit, and abort at very high altitude and velocity have all been successful. There have as yet been no booster malfunctions that would have prevented a safe



The illustration at left shows the capsule complete with retrorocket unit on heat shield and escape rig tripoded on top. Center, an illustration of the capsule's internal arrangement, with the Astronaut in flight position. The drawing at the right shows the position of the window and hatch added to the capsule at the suggestion of the Astronauts.

escape of the capsule from the scene of immediate danger.

The illustrations above depict the Astronaut in the capsule. The window and egress hatch are two modifications that have been made to the capsule since its initial design. The window, directly above the Astronaut's head, allows him to make observations independent of a periscope. The hatch employs primacord to cause it to fail and fall free when its handle is turned.

Safety Built In

The capsule is complicated by the redundant systems which have been added for increased safety. From right to left, one can distinguish the antenna can, two horizon scanners, parachute package, pitch and yaw jets and associated plumbing, periscope housing, instrument panel, side-arm controller, and sundry electronic and power packages. The environmental-control system is mainly below the Astronaut's couch. The capsule is completely automatic, but provisions have also been made for piloted operation. Each system has a backup; and in the area of communications, there are several backups. There are two telemetry systems for sending back capsule and pilot data. Also, there are on-board records which collect the same information sent by telemetry.

The Astronaut may take over completely and perform all the functions of the automatic control system. Because of the parallel manual system, he will also be able to fly any mode that might fail on the automatic system.

Let us look at a few of the capsule systems of special interest, beginning with the instrument panel, shown on page 73. The controls and displays on this panel are grouped as to function. The group on the left side has various pilot controls, such as those concerned with the attitude-control system and the retrorockets. The two large handles are for decompression and repressurization. Decompression would be used to extinguish a fire.

The next group, a sequencing display, consists of a series of lights—red and green—to indicate whether various functions did or did not occur at the proper time. The handle just to the left of each light is the pilot's control to override and correct the failure of any particular function. The light at the very top of this group is the abort light, which comes on if an abort is initiated. If the abort does not occur, the pilot can abort by using his left-hand grip. The switch immediately under the abort light is the pilot's "ready" switch. This switch is used prior to launch to light up a "ready" light on the test conductor's panel in the blockhouse.

The next series of dials are flight instrumentation. The dials indicate acceleration, rate of descent, altitude, and the fuel supply in the hydrogen-peroxide tanks. The top center of the panel is the attitude display, which shows rate and attitude in pitch, roll, and yaw. The Astronaut's control of attitude will be aided by (CONTINUED ON PAGE 73)

Fluorine solid propellants

This potent element, at the top of the list as an energetic molecule, tempts the researcher with its potential for very high performance in several formulations of solid propellant

By Milton Farber

ROCKET POWER/TALCO RESEARCH CENTER, PASADENA, CALIF.

Milton Farber is vice-president and director of the Rocket Power/Talco Research Center in Pasadena, Calif., in charge of research on high-energy fuel polymers, metal hydrides, and oxidizer molecules of high-energy content, as well as ion and plasma systems. Farber formerly headed the Propulsion Laboratory at Hughes Aircraft and was associate director of research and head of the Astronautics Laboratory at Aerojet-General. His previous assignments included nine years as senior research engineer at the Jet Propulsion Laboratory of Cal-Tech, pilot plant supervisor and senior research engineer for the Manhattan Project at Oak Ridge, and affiliations with Atlas Powder Co. and Colloidal Products Ltd. He received his B.S. degree in chemistry from the Univ. of California and his M.S. in chemical engineering from the Univ. of Minnesota and has two and one-half years toward a Ph.D. at the Univ. of California.

AT THE end of World War II, solid-propellant rockets were small, utilized heavy combustion chambers, and were inefficiently loaded with low-energy propellants. Artillery rockets with velocities greater than 1500 fps were nonexistent. Contrasted with the liquid-propellant V-2 stage of development, the solid-propellant rocket appeared in a different class altogether. Then the Jet Propulsion Laboratory advanced the state of the art of solids with the casebonded, rubber-fuel, internal-burning propellant grain used with thin-walled high-strength motor cases. Thereafter, the application of solid propellants to large, high-performance rocket vehicles was feasible (see first reference at end of article). For example the Minuteman ICBM is a result of this early work.

Since the late 1940's, progress with solid-propellant rockets has come variously from design, hardware, and chemical improvements. Not forgetting that advances in design and hardware have been truly significant, I would like primarily to discuss chemical improvements, especially the potential gains possible from such propellant.

The early solid propellants were adapted from the explosives industry and consisted of materials compounded from nitroglycerine and nitrocellulose. These materials formed the basis for today's double-base propellants. Other oxidizing materials, such as ammonium perchlorate and ammonium nitrate, were mixed with various liquids, such as asphalts and tars, which would harden upon standing or heating. These propellants became known as composites.

Through the years, more suitable substitutes for the asphalts and tars have been made through research in polymerizable binders. These materials included the sulfur and butyl rubbers, polyurethanes, acrylates, and numerous other hydrocarbons. During the early years of solid-propellant development, the composites consisted chiefly of a polymerizable hydrocarbon binder and an oxidizing salt. Recently, the addition of a light metal, such as aluminum in finely powdered form, to both the double-base and composite propellants has improved their performance. The increase has been chiefly due to the high energy per unit weight resulting from the combustion of the aluminum to its oxide. This energy heats the combustion gases to a higher temperature than was possible previously with propellants consisting of only binder and oxidizer.

The chief performance parameter for (CONTINUED ON PAGE 40)

Kodak reports on:

little white specks that move . . . stimulating observers to perceive more facts . . . the parts-per-billion business

A tip for radiographers

Little white specks have been appearing on radiographs of zirconium alloys. Since one of the principal reasons for radiographing zirconium alloys in the first place is for detection of tiny tungsten inclusions, this is not surprising. What has surprised the radiographers has been that most of the little white specks appear in different places on two successive films of the same part! Or even on two films made of the same part simultaneously!

Upon investigation* it turns out that the phenomenon does not contain enough high science to be worth the exclamation points. The moving specks are dandruff, cigarette ashes, lint, and such rubbish. So help us!

The junk gets picked up when the customer loads the film into the cardboard exposure holders. These often contain lead foils between which the film nestles. Besides serving as a filter to modify radiation quality, the lead emits electrons to intensify the image density. The junk simply casts electron shadows.

So we published a little paper in *Nondestructive Testing*. We said that in this specialized type of radiography for small inclusions it might be well to put cardboard under the front lead screen and use the lead only as a filter. We also advised surgical cleanliness, a darkroom under slight positive air pressure, and no smoking. This supplementary advice isn't really necessary if you don't try to shave exposure time by putting the lead in contact with the film, but it sounds wholesome. Furthermore, this line of thought led to the question of why make the radiographer load the film into a cardboard exposure holder in his own darkroom. Why not do it for him in our surgically clean, slight-positive-air-pressure, no-smoking factory?

We couldn't think of a good reason why not.

Kodak Industrial X-ray Film, Type M (*the maximum resolution type*) *is now available from x-ray dealers in a* Ready Pack *form, enclosed in individual, disposable, light-tight packets.*

*We needn't have investigated. We could have just dropped off the film, scooped up our money, and run, tarrying only long enough to suggest that 1) two films be routinely made of every part and then compared to distinguish moving white specks from real white specks; and 2) somebody should do a Ph.D. thesis on the effect. Sales would have doubled.

He knows everything about photography except how to make film.

He makes the world's best high-speed color film emulsions but tries to photograph pretty scenery through a dirty windshield.

At one of the 170 high-speed camera stations which instrument the 20,000-foot supersonic sled track at Edwards Air Force Base, Lt. Col. Earl R. Strandberg makes the acquaintance of Kodak's Walter A. Fallon. Colonel Strandberg, as chief of the Photographic Branch, has responsibility for quantitatively documenting all phenomena encountered in impact tests, static firing of rocket engines, and other activities of the Air Force Flight Test Center. Mr. Fallon, who is in charge of Kodak's color film emulsions, is visiting to observe the demands to be met by his latest products, a reversal film and its companion duplicating film. They strongly enhance information capacity through fine color distinction, sharpness, and extreme speed.

The names of the new products are *Ektachrome ER Film* and *Ektachrome Reversal Print Film*. They have a realistic quality that stimulates observers to perceive facts in super-slow-motion movies that would be lost without color.

To Walt Fallon the scenic drive through the mountains to check them out with the Colonel brought him near culmination of a hard campaign. To the Colonel, however, they represent only another step in a long history of increasing the usefulness of photography. In 1927 he talked a high school coach into letting him be the first man —more accurately, the first boy—ever to film an entire football game for purposes of analysis and self-improvement.

For information about color photographic materials for recording work, write Photorecording Methods Division, Eastman Kodak Company, Rochester 4, N. Y.

Spectroscopy in electronics

We wish we could inspire several dozen more persons to enter the craft of emission spectrography. They would become customers for *Kodak Spectrum Analysis Plates* and *Films* as well as occupants of a secure place in technical society, one of waxing importance.

To convince that the importance indeed waxes we could send copies of a disquisition written by one of our dealers, a gent willing to undertake some deep thinking and digging out of useful information in hope of the favor of an order.

Think of the old days, he suggests, when electronics meant radio and the man at the end of the radio assembly line was given plenty of adjustable resistors, capacitors, and coils on the chassis to adjust in compensation for the unpredictable characteristics of the vacuum tubes. Electronics isn't that way any more, he implies. Today electronics is supposed to assume that its solid-state devices and the cathodes of its vacuum tubes will behave predictably within very narrow limits.

And what sets these limits?

Among other things, the presence or absence of certain chemical elements in the range of parts per billion.

How determined?

By emission spectrography.

Is this easy?

Not particularly.

What's one way to start surveying the techniques?

Writing for a copy of "Spectroscopy in Electronics" to Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

Kodak
TRADE MARK

The Visicorder records

Unretouched Honeywell Visicorder record, actual size.

This study of the drop in voltage load on an Allis-Chalmers alternating current generator was directly recorded by a Model 906 Honeywell Visicorder.

In this transient reactance test, made by design engineers at the Allis-Chalmers Norwood Works, the generator was operated at full voltage, and then a dead short was applied to the terminals. When such a sudden load is thrown upon a generator, the voltage drops because of the inherent characteristics of the generator. This voltage "nosedive" is so rapid that a voltage regulator cannot immediately correct the voltage and bring it up to normal. Because of this time delay while the regulator is catching up, motor contacts and other devices on the line may drop out, lights may blink objectionably, and electronic devices may function erratically. For these reasons, these studies of time as related to generator characteristics are very important to better generator design. The Visicorder's ease of operation, calibration, and immediate readout made it ideal for these studies.

N. O. Risch and F. R. Manning, design engineers at Allis-Chalmers Norwood Works, study a Visicorder chart of voltage-drop tests on a generator.

ds

generator voltage load-drop

The Honeywell Visicorder is the pioneer, completely proven, and unquestioned leader in the field of high-frequency, high-sensitivity, direct-recording ultra-violet oscillography. Here are some of the reasons why Visicorders provide the most accurate analog recordings available: constant flat response and sensitivity of galvanometers; grid-lines simultaneously recorded with traces to guarantee exact reference regardless of possible paper shift or shrinkage; flash-tube timing system for greater accuracy of time lines; superior optics for maximum linearity of traces.

No matter what field you are in . . . research, development, computing, rocketry, product design, control, nucleonics . . . the high-frequency (DC to 5000 cps) Visicorder Oscillograph will save you time and money in data acquisition.

Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

Reference Data: write for Bulletins 1108, 1012, and HC906B.

Minneapolis-Honeywell Regulator Co.
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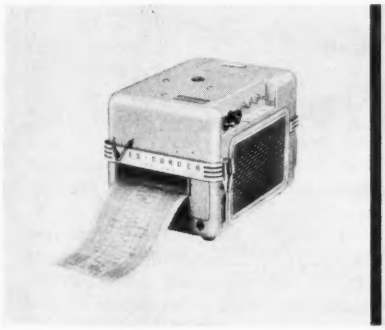
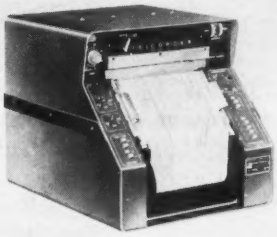
5200 E. Evans Avenue, Denver 22, Colorado



Recent Models of the 906 Visicorder incorporate time lines and grid lines and record up to 14 simultaneous channels of data.



The NEW Model 1108 Visicorder, with many automatic features and the convenience of pushbutton controls, is ideal for intermediate uses requiring up to 24 channels of data.

The Model 1012 Visicorder is the most versatile and convenient oscillograph ever devised for recording as many as 36 channels of data.

Honeywell

Industrial Products Group

75th YEAR
PIONEERING THE FUTURE

Space Shape for Solids

(CONTINUED FROM PAGE 27)

versus-time performance in the motor chamber. Without going into the complex nonsteady-state interactions in a solid motor, we can point out that in cylindrical systems the region of highest pressure will be at the head end and that the region of highest mass flow and greatest velocity will be at the nozzle end. These conditions cause the propellant to burn progressively faster than its nominal rate—that is, to burn unevenly, causing local fluctuations in pressure and leading to one area of the grain burning out before another (nasty slivers). This process is usually referred to as erosive burning.

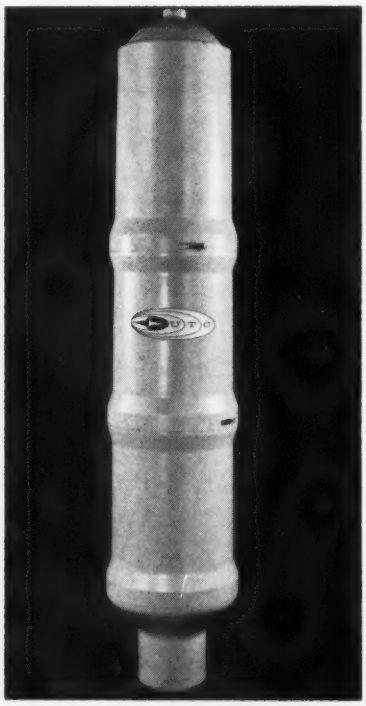
The erosive effects must be balanced against each other to obtain fairly even grain burning and consequent constant motor pressure and low sliver residue. Having a port that increases with the increase in mass flow along the perforation of the grain makes the task of balancing the internal conditions of the motor relatively simple. The cone angle of the conical motor can be defined so that the mass flow per unit area along the length of the charge is constant, thereby inducing the same degree of erosive burning throughout. This is a very important consideration for a large motor, which might lose the energy of thousands of pounds of propellant through uneven burning and sliver formation. Solving this problem with a cylindrical shell while striving to maintain a high volumetric loading of propellant would prove, we believe, a very knotty problem indeed.

As important as erosive burning are stress loads within the propellant grain upon chamber pressurization. These loads are most severe in the perforation and are proportional to the volumetric loading. Since the propellant web thickness in the conical motor is constant, the volumetric loading of the apex segment is higher than in any subsequent segment. Therefore, solving the interior physical criteria of the apex segment essentially eliminates this problem with the remaining segments.

Here the segmented approach and the cone shape conjoin to waive one of the major objections to the development of large solid rockets. You do not need to static test a large number of the total motor to qualify it for operational use. You test a large number of the *smallest segment* in the total motor to qualify the total design, and then only a handful of each of the larger segments. This also makes a statistical control of manufactured lots of motor segments possible at a fractional cost of the total cost of manufacture. This approach obviously saves time and the cost of major new facilities.

There are several other important points bearing on the practicality and economics of the segmented cone-shaped motor.

The success of the segmented conical-shaped design depends to a large degree, oddly enough, on excellence in a piece of mechanical design: The means of joining segments of the rocket. The little test motor as shown below uses a lockwire for this purpose, but it is just for demonstration of the motor's principles. United Technology has developed with its own funds a method of joining specifically suited to the design. This method of joining will add no more than 1 per cent to the weight of a segmented rocket motor as compared to nonsegmented construction.



This small motor has already tested the segmented-cone concept in static firings.

As to grain manufacture, notice that the cone shape makes it possible to withdraw the die that forms the perforation with little likelihood of tearing the surface of the perforation. A fraction of an inch movement of the die frees it from the grain. This can save a good deal of expense and promote reliability.

We might mention the fabrication of motor cases. Our studies indicate that conical segmented cases will come within 5 per cent of the cost of plain cylinders.

Also, we believe that other hardware problems for these large motors, such as nozzles, are well within the state of the art.

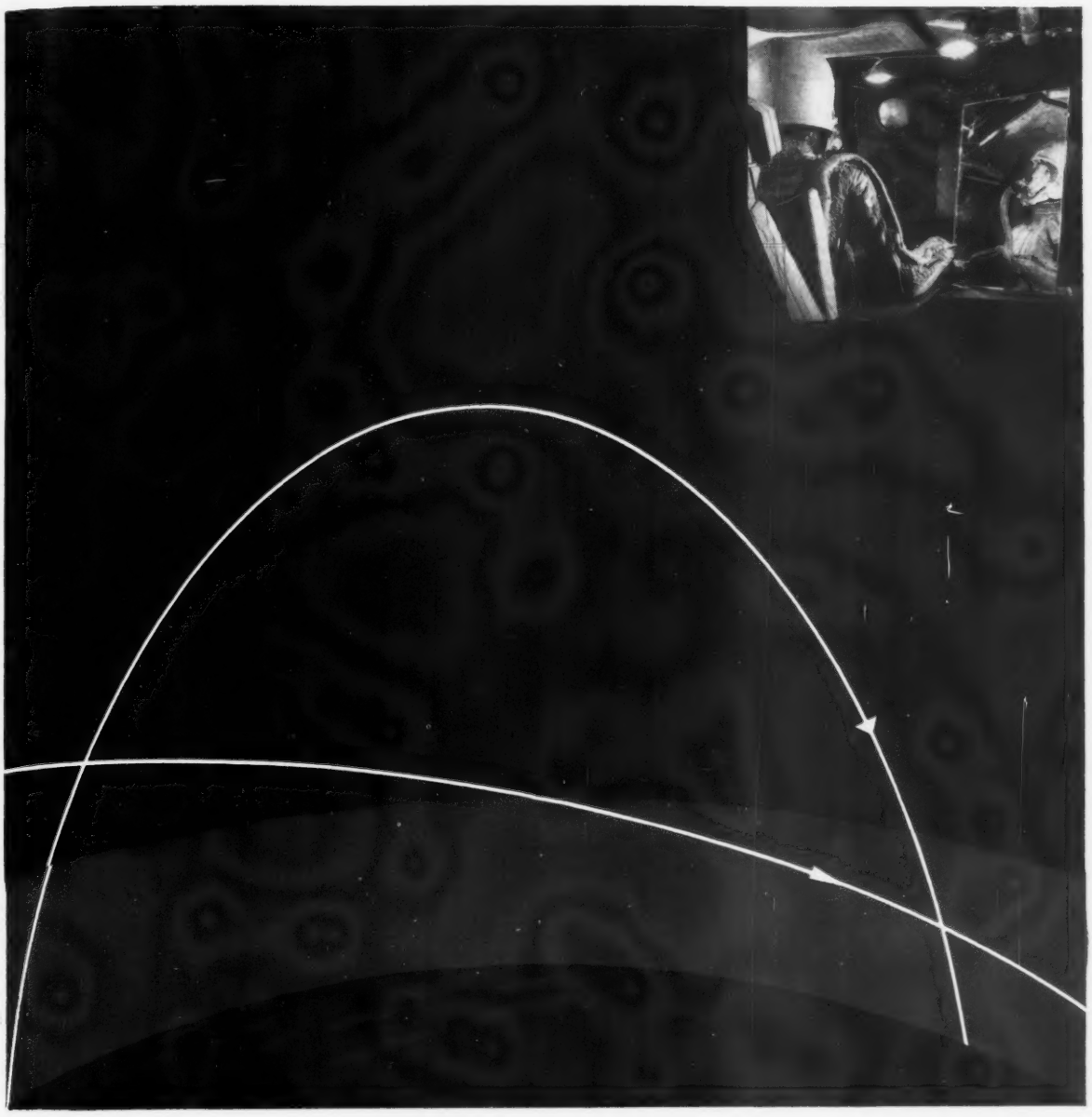
Finally, we can mention ballistic performance and the versatility of the segmented conical rocket for various space missions. Consider first boosters for launching space vehicles. If each segment is designed on a weight-limited basis, that is, maintaining maximum weights that are transportable over the nation's highways and railroads, then as an approximate order of magnitude each segment will deliver 15,000,000 lb-sec of total impulse. The actual value of this number is dependent upon many criteria, such as specific impulse, thrust level, and inert component designs; but it does represent a good talking figure.

Impulse Level

Given a booster requirement, then, the appropriate number of segments can be combined to provide the requisite impulse level—three segments will deliver approximately 45-million lb-sec, seven segments approximately 105 million, etc.—until length-to-diameter ratios, as imposed by system structures, become the limiting factor. From standpoint of internal ballistics there is no upper limit on length.

If a single unit within reasonable lengths cannot be provided, then it becomes advantageous to cluster. At this point the operations people have unlimited flexibility. Based on aerodynamic considerations and upper-stage geometry, a cluster of four units three segments long, three units four segments long, or two units six segments long may be employed. Structural weights imposed by clustering are relatively insignificant, since mass fraction, per se, is not too important a parameter in large boosters.

The photos of models on page 27 show the other ways that segmented conical motors can be tailored to missions—the single large booster for other powered stages, the three-stage satellite launcher, etc. With a store of segmented conical units, the operations people will have a virtual do-it-yourself kit of rocket motors for any major mission expected for some time to come—any mission off the shelf! This can conservatively be called an advance in the state of the art. ♦♦



Ballistic and boost-glide flight paths

These flight paths, arcing through space and re-entering the atmosphere, are characteristic of the paths of a ballistic missile and a boost-glide vehicle. In both areas, Boeing holds major contract responsibilities. Boeing is weapon system integrator for the solid-fuel ICBM, Minuteman, and as part of a USAF-NASA research program, is developing Dyna-Soar to study the problems of manned space flight. The Dyna-Soar vehicle will be capable of re-entering the atmosphere and making a normal controlled landing.

Boeing scientists and engineers, in addition, are advancing the state of the art in many areas: advanced military and commercial aircraft, hypersonic flight, space crew environments, vertical and short take-off and landing aircraft, gas turbine engines, anti-submarine warfare systems, among others.

Professional-Level Openings

These and other future-oriented programs at Boeing offer outstanding career openings to professional specialists in the scientific and engineering disciplines, as well as in a broad spectrum of company activities in other-than-engineering areas. You'll find at Boeing a professional environment conducive to deeply rewarding achievement. Drop a note, now, to Mr. John C. Sanders, Professional Personnel Administrator, Dept. ARE, Boeing Airplane Company, P. O. Box 3822, Seattle 24, Wash.

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Fluorine Solid Propellants

(CONTINUED FROM PAGE 34)

propellants is specific impulse, *Isp*, which is proportional to the half-power of the difference in heats of the combustion gases in the chamber and of those gases leaving the rocket at the nozzle exit:

$$Isp \sim \sqrt{\frac{CpTc - CpTe}{M}}$$

where $CpTc$ is enthalpy of combustion gases in chamber,
$CpTe$ is enthalpy of combustion gases at exit of nozzle, and
M is average molecular weight of combustion gases.

You can see that it is desirable to have as large a difference between the exit and chamber heats–$CpTc - CpTe$ or $\Delta H\ (Tc/Te)$–and as low a value for M as possible. When the combustion products contain gases only, the expansion process follows very closely the laws of thermodynamics governing an adiabatic and isentropic expansion; that is, $Te = Tc(Pe/Pc)^{(\gamma-1)/\gamma}$ where Pe/Pc = ratio of chamber pressure to exit pressure and γ = ratio of specific heats, Cp/Cv. In a completely gaseous combustion system, a large ratio for Pe/Pc (obtained by expansion in a vacuum) will lower the value of Te, which in turn will increase the value for $\Delta H(Tc/Te)$ and therefore result in a higher *Isp* for high-altitude flight. However, further increases must come from an increase in the chamber enthalpy and a decrease in the molecular weights of the combustion gases.

It is desirable to have a high value for $CpTc$, the enthalpy of gases in the combustion chamber, since this will allow a greater spread during expansion and will increase the value of $\Delta H(Tc/Te)$.

The experimental values obtained for the performance of liquid propellants and nonmetallized solid propellants follow closely values predicted from theoretical performance calculations. In metallized solid propellants, the combustion gases may contain as much as 40 to 50 per cent of solid or liquid particles due to the high vaporization temperatures of the metallic oxides. The law governing the conservation of entropy declares that, if the entropy is to remain constant the entropy in the chamber must equal the entropy at the exit of the nozzle. Stated in mathematical form: $\Sigma(n_iS_i)c - n_gR\ln p_c = \Sigma(n_iS_i)_e - n_gR\ln p_e$ where n_i and S_i are the individual mole fractions and entropies of the various combustion products, including solids. The entropy change due to molecular mixing is for simplicity included in these terms. The pressure effect on the entropy, $n_gR\ln p$ (where n_g is the total number of moles of gas present), is the factor which determines the amount of enthalpy converted to energy. It is readily ascertained that when n_g is only a fraction of the total of the combustion products, the value for $\Delta H(Tc/Te)$ will suffer proportionately.

Expansion Ratios

The highest performance for any propellant system would be obtained when the gases leave the nozzle at the temperature of the surrounding atmosphere. However, in theory this would require an infinite expansion ratio. Actual nozzles utilized for space flight have expansion ratios which correspond to exit pressures considerably higher than the surrounding space vacuum. For expansion through these real nozzles, low-molecular-weight gases are necessary to obtain a low value for the exit temperature. When the exhaust, which contains solid particles, is expanded to near-vacuum pressures, the gain in performance is limited by the additional amount of cooling that can be obtained by the exhaust gases. Experiments have verified the fact that aluminized propellants do not yield substantial improvement in performance in high-altitude simulation chambers as compared to the results obtained at sea level.

Since the important parameter for propellant energy is the maximum value for $\Delta H(Tc/Te)$ per unit weight, the search for propellant ingredients must include compounds that will yield high heats of reaction with low-molecular-weight combustion gases, together with a minimum amount of solid or liquid particles. The hydrocarbon binders utilized in solid propellants contain principally carbon and hydrogen and some smaller amounts of oxygen and nitrogen. The binder and the light metal must obtain oxygen from an oxidizing salt, such as ammonium perchlorate. The nitrogen present in the propellant does not contribute to the energy available during combustion and provides a gas of moderately heavy molecular weight. Examples of this may be seen in several liquid-propellant systems containing hydrazine as fuel. The performance of these systems, when compared to hydrogen-fuel systems, are lowered by the amount of nitrogen present in the propellant mixture. This can be seen from the table on page 42. This is true even though hydrazine is an endothermic molecule.

Heat of Formation of Several Light-Metal Oxides and Fluorides*

Oxide	H_f 298 K (kcal/mole)	Fluoride	H_f 298 K (kcal/mole)
Li_2O	−142.4	LiF	−146.3
BeO	−145	BeF_2	−227
B_2O_3	−302.0	BF_3	−265.4
MgO	−143.8	MgF_2	−263.5
Al_2O_3	−396.2	AlF_3	−311

* Values are taken from NBS Circular 500.

Therefore, to obtain a solid propellant which will yield a high performance, the following criteria must be met:

1. The material must have a high heat of reaction per unit weight.
2. The amount of liquid or solid particles formed during the combustion process must be small.
3. All propellant ingredients should enter the combustion process and contribute to the available energy.
4. The average molecular weight of the gases must be low.

The solid propellants available for immediate application suffer in one or several of these criteria. The propellants containing completely gaseous exhausts have comparatively low heats of reaction and usually carry elements that contribute little or no energy. The propellants with solid exhaust particles sustain loss in performance due to the lower weight percentage of gas available for expansion through the nozzle.

The average energy available upon the combustion of a solid propellant is approximately 2 kcal/gm of material. However, the light metal oxides contribute on the order of 3 to 4 kcal/gm to the available heat. Therefore, it is desirable to have as much of the metal as possible in the formulation.

Considering the inclusion of all four of our criteria as necessary propellant characteristics, the author concluded several years ago that light metals yielding gaseous metal products during combustion must be included in propellant formulations.

The search for suitable gaseous metal combustion products with high available energies leads to the fluorine atom. Most metal oxides have high-vaporization temperatures and are solids or liquids at rocket combustion temperatures, but the metal fluorides are usually present in a highly stable gaseous form at these same temperatures. Although all solid-propellant binders in the past and those in use today are hydrocarbons, an entirely new field of binder materials containing fluorine remains to be investigated

Pneumatic Power In A Portable Package!

These ground service carts supply clean, high-pressure air for any airport use—could even power a jet engine starting system! They also can pressurize missile pneumatic systems, shock isolation and air suspension systems, or ground support equipment. Can even run air tools. They are an ideal source of high-pressure air for in-plant use, too.

Some particulars: 4 cfm compressor (illustrated) 5,000 psi; 900 cubic inch wire wound steel air reservoir; moisture separator and chemical drier; outlet pressure regulator; with electric drive (gasoline drive available). Approximate weight 150 pounds. For more information, write Kidde today.

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– fluorocarbons, fluorohydrocarbons, and other organic molecules containing fluorine through nitrogen or oxygen bonds (N-F or O-F compounds).

The chief advantage of using fluorine in a solid-propellant formulation is the resultant formation of highly energetic gaseous metal fluorides as exhaust products. Generally, these metal fluorides have as high or higher a chemical enthalpy per unit weight of propellant as their oxygen counterparts. The table on page 40 gives heat of formation of some light metal oxides and fluorides. Additional increase in performance results from the contribution of the gaseous metal fluoride expanding through the nozzle.

A previous publication (see references) by the author has shown that, in general, fuel-rich systems yield higher specific impulses at sea level, while stoichiometric systems are superior for high-altitude applications. This reversal in performance stems from the dissociation of molecules (formed during the combustion of the propellant in the chamber at high temperatures) into free radicals. At sea-level exhaust pressures, these radicals are incompletely associated, so that considerable energy is lost in the expansion process. However, in expanding to vacuum, there is sufficient time for the recombination to occur, resulting in a subsequent increase in performance. Spacecraft make the consideration of vacuum performance mandatory. It is felt that in this category the performances of the highly energetic fluorine solid propellants containing light metals will exceed those of the conventional aluminized hydrocarbon propellants.

There has been a contention that the strong C-F bond may decrease the amount of available energy in a solid-propellant system. The C-F bond is indeed a stable bond (the bond strength, D_0, is 110 kcal) which contributes to the excellent physical properties of the fluorocarbon molecule. However, when utilized in a propellant formulation, it is the net available energy which is of importance; that is, the energy of the combustion product less the energy of the reacting material. Fluorocarbon molecules have heats of formation ranging between 1 to 1.5 kcal/gm. When these compounds react with light metals, total net energies of over 2 kcal/gm are produced. These compare well with the energies of 1.5 to 2.0 kcal/gm derivable from hydrocarbon materials. Since elemental fluorine is a powerful oxidizing agent, the judicious choice of fluorine compounds will yield large net energies upon combustion.

Consideration of additional advantages of fluorocarbon binders as compared to the conventional hydrocarbon binders include:

(1) A fluorocarbon molecule acts as both oxidizer and fuel.

(2) Since the molecular weight of fluorine is 19 times that of hydrogen, the relative percentage of carbon is reduced considerably. Also, the maximum performance obtained from carbon is approximately 1 kcal/gm, which is considerably lower than the average performance of the propellant.

(3) Fluorocarbon materials have nearly twice the density of hydrocarbons.

(4) Fluorocarbons are stable at considerably higher temperatures than the hydrocarbons.

Performance of Hydrogen and Hydrazine

Propellant		Specific* impulse
Fuel	Oxidizer	(lb-sec/lb)
H_2	O_2	342
N_2H_4	O_2	275
H_2	F_2	362
N_2H_4	F_2	314

* Chamber pressure of 300 psia and exit pressure of 14.7 psia.

High Densities

Scientists at Rocket Power have been engaged in a research and development program which is concerned with the formulation of fluorocarbon propellants. As a result, Rocket Power has available several castable fluorohydrocarbons having densities of nearly twice that of the conventional hydrocarbon binder materials. These high densities alone increase the velocity for small fixed-volume rockets approximately 15 per cent above conventional propellants. The physical properties of these propellants are excellent. The fluorocarbon binders have generally excellent tensile strength and fairly good elasticity. They bond readily to smooth metals, plastics, and glass. The monomers are clear, dense liquids which polymerize at fairly low curing temperatures upon the addition of suitable catalysts.

The fluorine polymers have basically empirical formulas of the following type: $-[CH_xF_yO_z]$. These polymers, as well as the hydrocarbons, require high percentages of oxidizing salts to form energetic propellants. The constitution of the ideal binder would be formed of sufficient amounts of fluorine and oxygen to eliminate the need for an oxidizing salt. The propellant would consist of binder and metal or metal hydride. Performance of this propellant would be increased considerably. The physical properties would be excellent since the binder would consist of more than half the propellant weight as compared to present propellants in which the binder consists of only a small fraction of the propellant weight.

Rocket Power scientists are attempting to incorporate oxidizing groups including NF_2, ClO_4, NO_2, and OF into the fluorocarbon molecule. The most desirable group would be the OF, since both the oxygen and fluorine provide chemical enthalpy upon combustion. Although the nitrogen atom may lower the performance for vacuum flight, it may be necessary to include nitrogen in order to incorporate two fluorine or oxygen atoms, as in the NO_2 and NF_2 molecules.

The synthesis and polymerization of fluoroölefins with the oxidizing groups discussed above are being investigated at Rocket Power (see the third reference). Fluoroölefins under study include the perfluorocumulenes, tetrafluoroallene and perfluorobutatriene, the acetylenes, monofluoroacetylene, and 3,3,3-trifluoropropyne, perfluorobutadiene, and the dimer of tetrafluoroallene. The sensitivity of oxidizing groups to molecules of this type is decreased by the stabilizing effect of the C-F bond, whereas the C-H bond (hydrocarbon binder) is readily oxidized by strong oxidizing groups.

In summarizing, we should bear in mind that a propellant must have efficient performance together with excellent physical properties. The fluorine molecule is at the top of the list as an energetic oxidizer. Therefore, its successful incorporation in a polymerizable molecule will store a considerable amount of this energy for combustion.

The development of hydrocarbon solid-propellant research from its early days of cottonseed oil and asphalt tar mixtures to today's more sophisticated fuels has been a result of research and development. Today, fluorocarbon research is still in its infancy, with the promise, however, of providing the future solid propellants for both the missiles and spacecraft.

References

Summerfield, M., Shafer, J. I., Thackwell Jr. H. L., and Bartley, C. E., "The Applicability of Solid Propellants to High-Performance Rocket Vehicles," Jet Propulsion Laboratory Memorandum 4-17, October 1, 1947 (Confidential).

Farber, M. and Cox, A. Lucile, "Effects on Rocket Performance Resulting from Chemical Reactions in Expansion Processes," presented at the Propellant Thermodynamics and Handling Conference, July 20, 1959; to be published in the Proceedings of the conference, by the Ohio State Univ. Press.

Reed, Russell, Jr., "The Synthesis and Polymerization of Fluorocarbons Containing Difluoroamino Groups," presented at the 2nd NF Symposium, December 2-3, 1959, Pasadena, Calif.

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ARS news

ARS Announces Program for Space Power Systems Conference to be Held Sept. 27–30

Major aspects of energy conversion technology and its application to advanced power systems for space vehicles will be discussed at the AMERICAN ROCKET SOCIETY's Space Power Systems Conference, to be held September 27–30, at the Miramar Hotel, Santa Monica, Calif.

Conference Chairman Walter K. Deacon described the event as "the first major power systems conference in the country" and predicts over 1000 participants from government, military, and industry. Areas to be covered include present and predicted state-of-the-art basic research, component fabrication, and system design applied to power systems for space and orbital craft.

The four-day gathering will feature as principal speakers leaders in science, government, and the military. Presently scheduled to address the group at its daily luncheons are Maj. Gen. Marvin C. Demler, AF Director of Research and Development; Ernst Stuhlinger of Marshall Space Flight Center; and Chauncey Starr, president of Atomics International. The fourth luncheon speaker will be announced at a future date.

Specific topics to be discussed include thermoelectric and thermionic thermal converters, dynamic heat engines and electromechanical energy conversion, solar-energy sources, chemical-energy sources and storage mechanisms, nuclear-energy sources, nuclear-systems design, and solar-system design. Technical developments will be illustrated by hardware that tie in with the actual devices, systems, and components discussed during the technical sessions.

Co-sponsors of the conference are NASA, AF, AEC, and ARPA.

The scheduled program follows.

TUESDAY, SEPTEMBER 27

Thermoelectricity

9:00 a.m. **Satellite Room**

Chairman: Paul Egli, Office of Naval Research, Naval Research Laboratory, Washington, D.C.

Vice-Chairman: R. T. Carpenter, U. S. Atomic Energy Commission, Germanton, Md.

✦Physics of Thermoelectricity, A. C. Beer, Battelle Memorial Institute, Columbus, Ohio. (1272-60)

✦Thermoelectric Generator Materials, R. W. Ure and R. C. Miller, Research Laboratories, Westinghouse Electric Corp., Pittsburgh, Pa. (1273-60)

✦High-Temperature Semiconductors for Direct Thermoelectric Conversion, S. W. Kurnick, R. L. Fitzpatrick, and J. E. Leavy, General Atomics, Div. of General Dynamics Corp., San Diego, Calif. (1274-60)

✦Rare Earths as Thermoelectric Materials, R. C. Vickery, R. M. Muir, and E. V. Kleber, Nuclear Corp., Burbank, Calif. (1275-60)

✦Irradiation Effects on Thermoelectric Materials, Joseph C. Danko, Research Laboratories, Westinghouse Electric Corp., Pittsburgh, Pa. (1276-60)

✦Thermoelectric Elements in Space Power Systems, Douglas L. Kerr, Missile and Space Vehicle Dept., General Electric Co., Philadelphia, Pa. (1277–60)

✦Thermoelectric Element Design for a Modified Snap III Power Source for Space, H. Greenfield, Lockheed Missiles and Space Div., Sunnyvale, Calif. (1278-60)

✦The Use of High-Temperature Thermoelectric Materials (Silicides) for Power Generation in Space, S. E. Mayer and I. M. Ritchie, Transitron Electronic Corp., Wakefield, Mass. (1279-60)

✦Thermoelectric Materials for Space Cooling, Edward E. Gardner, Edwin L. Woisard, Research Laboratories, Whirlpool Corp., St. Joseph, Mich. (1280–60)

Thermionics

2:00 p.m. **Satellite Room**

Chairman: Wayne Nottingham, Massachusetts Institute of Technology, Cambridge, Mass.

Vice-Chairman: E. F. Redden, Wright Air Development Div., Wright-Patterson AFB, Ohio.

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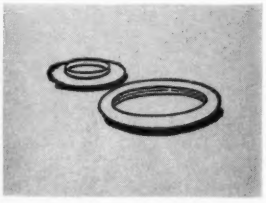

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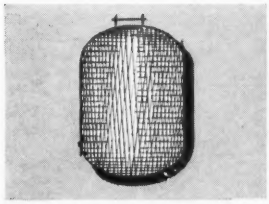

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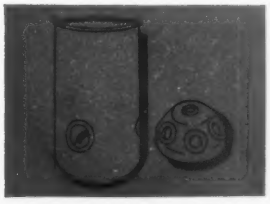

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On the calendar

1960

Aug. 1–3	Global Communications Symposium, sponsored by IRE and Army Signal Corps, Statler Hotel, Washington, D.C.
Aug. 3–6	Intl. Symposium on Rarefied Gas Dynamics, Univ. of Calif., Berkeley.
Aug. 8–11	American Astronautical Society Western National Meeting, Olympic Hotel, Seattle, Wash.
Aug. 8–12	AIEE 1960 Pacific General Meeting, El Cortes Hotel, San Diego, Calif.
Aug. 14–17	AIChE and ASME National Heat Transfer Conference, Statler Hilton, Buffalo, N.Y.
Aug. 15–20	**11th International Astronautical Congress, Stockholm, Sweden.**
Aug. 15–26	Summer Institute on Nondestructive Testing, Sacramento State College, San Francisco.
Aug. 23–25	1960 Cryogenic Engineering Conference, Univ. of Colorado, Boulder, Colo.
Aug. 29–Sept. 2	The Combustion Institute 8th International Symposium on Combustion, CalTech, Pasadena, Calif.
Aug. 31–Sept. 7	10th International Congress of Applied Mechanics, Congress Bldg., Stresa, Italy.
Sept. 7–9	ISA, AIChE, AIEE, ASME, and IRE Joint Automatic Control Conference, MIT, Cambridge, Mass.
Sept. 15–16	Annual Meeting of Armed Forces Chemical Assn., Sheraton-Park Hotel, Washington, D.C.
Sept. 19–21	1960 IRE National Symposium on Space Electronics and Telemetry, Shoreham Hotel, Washington, D.C.
Sept. 21–25	Air Force Assn. National Convention and Aerospace Panorama, San Francisco.
Sept. 26–29	American Welding Society National Fall Meeting, Hotel Penn-Sheraton, Pittsburgh, Pa.
Sept. 26–30	3rd ISA Instrument-Automation Conference and Exhibit, N.Y. Coliseum, N.Y.C.
Sept. 27–30	**ARS Power Systems Conference, Miramar Hotel, Santa Monica, Calif.**
Oct. 3–5	IRE Annual Meeting of the Professional Group on Nuclear Science, Gatlinburg, Tenn., sponsored by PGNS and Oak Ridge National Lab.
Oct. 4–6	IRE Conference on Radio Interference Reduction, Chicago, Ill.
Oct. 5	Technical Conference on "Plastics vs. Corrosion," sponsored by Society of Plastics Engineers, Mark Hopkins Hotel, San Francisco.
Oct. 10–12	**ARS Human Factors and Bioastronautics Conference, Biltmore Hotel, Dayton, Ohio.**
Oct. 12–14	AF Symposium on Astronautics, sponsored by AFOSR and Society of Automotive Engineers, Ambassador Hotel, Los Angeles.
Oct. 14–15	Symposium on Revolution in High-Speed Photography, Society of Photographic Scientists & Engineers, Washington, D.C.
Oct. 20–21	Hypervelocity Projection Techniques Conference, Univ. of Denver, Colorado.
Oct. 24–26	Medical and Biological Aspects of the Energies of Space Symposium, sponsored by USAF Aerospace Medical Center (ATC), Hilton Hotel, San Antonio, Tex.
Oct. 26–27	1960 Computer Applications Symposium sponsored by Armour Research Foundation, Morrison Hotel, Chicago.
Oct. 27–28	IRE Professional Group on Electron Devices Meeting, Shoreham Hotel, Washington, D.C.
Nov. 3–4	**ARS and U.S. Naval Postgraduate School Conference on Electrostatic Propulsion, Monterey Calif.**
Nov. 15–16	Symposium on Engineering Application of Probability and Random Function Theory, Purdue Univ., Lafayette, Ind.
Nov. 15–17	AF-Navy-Industry Propulsion Systems Lubricants Conference, sponsored by ARDC & Southwest Research Institute, Hilton Hotel, San Antonio, Tex.
Nov. 21–26	Colloquium on Space Research sponsored by Argentine National Committee for Space Research and Argentine Interplanetary Society, Buenos Aires, Argentina.
Dec. 5–8	**ARS Annual Meeting and Astronautical Exposition, Shoreham Hotel, Washington, D.C.**
Dec. 13–15	Annual Eastern Joint Computer Conference, Hotel New Yorker and Manhattan Center, New York, N.Y.
Dec. 27	AAS 127th Annual Meeting, New York, N.Y.

✦Review of the Physics of Thermionics, Wayne Nottingham, Massachusetts Institute of Technology, Cambridge, Mass. (1281–60)

✦Cesium Converter Studies, Volney C. Wilson, General Electric Co., Schenectady, N.Y. (1282-60)

✦Parametric Optimization of the Plasma Diode, Ned Rasor, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1283-60)

✦Experimental Research on Plasma-Thermionic Energy Converters, Karl G. Hernqvist, Radio Corp. of America, Princeton, N.J. (1284-60)

✦Plasma-Thermionics, Harold W. Lewis, Univ. of Wisconsin, Madison, Wis. (1285-60)

✦Chemistry of Fuel-Element Cathode Materials, Melvin Bowman, Los Alamos Scientific Laboratory, Univ. of California, Los Alamos, N.M. (1286-60)

✦A Nuclear-Thermionic Fuel-Element Test, L. Yang, H. Garvin, and R. Howard, General Atomics, Div. of General Dynamics Corp., San Diego, Calif. (1287–60)

WEDNESDAY, SEPTEMBER 28

Photovoltaic Cells

9:00 a.m. **Satellite Room**

Chairman: Paul Rappaport, Radio Corp. of America, Princeton, N.J.

Vice-Chairman: William Cherry, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J.

✦The Photovoltaic Effect and Solar-Energy Converters, Joseph J. Loferski, Radio Corp. of America, Princeton, N.J. (1288-60)

✦Advances in Silicon Solar-Cell Development, Martin Wolf, Hoffman Electronics Corp., El Monte, Calif. (1289-60)

✦Thin-Film Silicon Solar Cells James F. Elliott, General Electric Co., Syracuse, N.Y. (1290–60)

✦Evaporated CdS Film Photovoltaic Cells, D. Gorski, F. Shirland, and A. Middleton, Harshaw Chemical Co., Cleveland, Ohio. (1291–60)

✦Integrally Composed Variable Energy Gap Solar Cells, Louis Stone, Research Dept., Eagle-Picher Co., Miami, Okla. (1292-60)

✦Some Theoretical Aspects of the Physics of Solar Cells, Hans Queisser and William Shockley, Shockley Transistor Corp., Mountain View, Calif. (1293-60)

✦Electron Bombardment of Silicon Solar Cells, R. G. Downing, Space Technology Laboratories, Inc., Los Angeles, Calif. (1294-60)

✦Radiation Damage to Solar Cells in Satellite Space Power Systems, J. M. Denney, Space Technology Laboratories, Inc., Los Angeles, Calif. (1295-60)

✦Solar-Cell Design Considerations, William V. Wright, W. Evans, Electro-Optical Systems, Inc., Pasadena, Calif., and A. S. Mann, Spectro Laboratories, Los Angeles, Calif. (1296-60)

✦The Use of Vacuum Deposited Coatings to Improve the Conversion Efficiency of Silicon Solar Cells in Space, Alfred Thelen, Optical Coating Laboratory, Inc., Santa Rosa, Calif. (1298-60)

Electrochemical Cells

2:00 p.m. **Satellite Room**

Chairman: Arthur Daniel, U.S. Army Signal Research and Development Laboratory Fort Monmouth, N.J.

Vice-Chairman: H. W. Fox, Office of Naval Research, Washington, D.C.

✦General Evaluation of Chemicals for Re-

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generative Fuel Cells, James King, Frank A. Ludwig, and J. J. Rowlette, Electro-Optical Systems, Inc., Pasadena, Calif. (1299-60)

✦Photoelectro-Chemical Cells, Morris Eisenberg and H. P. Silverman, Lockheed Missiles and Space Div., Sunnyvale, Calif. (1300-60)

✦Resume of Thermally Regenerative Fuel-Cell Systems, Robert E. Henderson, B. Arguss, and W. G. Caple, Allison Div., General Motors Corp., Indianapolis, Ind. (1301-60)

✦Fuel Cells for Astronautic Application, G. Starkey, Wright Air Development Div., Wright-Patterson AFB, Ohio. (1302-60)

✦Regenerative Hydrogen-Oxygen Fuel Cell, Frank A. Ludwig, Electro-Optical Systems, Inc., Pasadena, Calif. (1303-60)

✦Fuel Cells with Ion-Exchange Membranes, Walter Juda and Charles E. Tirrell, Ionics, Inc., Cambridge, Mass. (1304-60)

✦Regenerative Ion-Exchange Membrane Fuel-Cell Developments, M. D. Read, Missile and Space Vehicle Dept., General Electric Co., Philadelphia, Pa. (1305-60)

✦Closed-Cycle Monopropellant Fuel-Cell System Employing Radiation Generated or Photochemically Generated Ozone, Jeff W. Eerkens, Aerojet-General Nucleonics, San Ramon, Calif. (1306-60)

✦Secondary Batteries for Energy Storage in Space, Irving M. Schulman, Missile and Space Vehicle Dept., General Electric Co., Philadelphia, Pa. (1307-60)

✦Battery Considerations for a Communications Satellite, U. B. Thomas, Bell Telephone Laboratories, Inc., New York, N.Y. (1308-60)

THURSDAY, SEPTEMBER 29

Solar Systems

9:00 a.m. **Satellite Room**

Chairman: George Sherman, Wright Air Development Div., Wright-Patterson AFB, Ohio.

Vice-Chairman: Curtis Kelley, Wright Air Development Div., Wright-Patterson AFB, Ohio.

✦Solar Cell–Storage-Battery Space Power System Review, Nathan W. Snyder, Advanced Research Projects Div., Institute for Defense Analyses, Washington, D.C. (1309-60)

✦Vanguard-Courier-Pioneer-Tiros-Explorer, George Hunrath, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J.

✦Preliminary Design and Performance Evaluation of a Solar-Thermoelectric Flat Plate Generator, R. J. Campana, and J. B. Roes, General Atomics, Div. of General Dynamics Corp., San Diego, Calif. (1310-60)

✦Solar Thermionic Electric Power System, D. L. Purdy, Missile and Space Vehicle Dept., General Electric Co., Philadelphia, Pa. (1311–60)

✦Solar Concentration Associated with the Stirling Engine, Robert E. Henderson, H. D. Wilsted, and Harvey W. Welsh, Allison Div., General Motors Corp., Indianapolis, Ind. (1312–60)

✦Solar—(Mechanical Turbomachinery) 15 kw(e) Powerplant, B. Macauley and Eugene Zwick, Sundstrand Turbo Div., Sundstrand Corp., Pacoima, Calif. (1313–60)

✦Solar Concentrators for High-Temperature Space Power Systems, Donald H. McClelland, Electro-Optical Systems, Inc., Pasadena, Calif. (1314-60)

A Panel Discussion on Results of Solar-Cell Storage-Battery Systems Development for U.S. Space Vehicles

Moderator: Nathan W. Snyder, Advanced Research Projects Div., Institute for Defense Analyses, Washington, D.C.

✦Samos—Midas—Discoverer, Charles Burrell, Lockheed Missiles and Space Div., Sunnyvale, Calif.

✦Advent, Richard Karcher, General Electric Co., Philadelphia, Pa.

✦Pioneer, Raymond Miller, Space Technology Laboratories, Inc., Los Angeles, Calif.

✦Ranger, Robert Hamilton, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif.

✦Transit, Walter Scott, Applied Physics Laboratory, Johns Hopkins Univ., Silver Spring, Md.

✦Tiros, Seymour H. Winkler, Radio Corp. of America, Princeton, N.J.

Dynamic Engines, Plasma Generator

2:00 p.m. **Satellite Room**

Chairman: Gordon Banerian, Aerojet-General Nucleonics, San Ramon, Calif.

Vice-Chairman: A. Orsini, Walter Kidde and Co., Inc., Belleville, N.J.

✦Stirling Engine Development for Space Power, Russell S. Hall, M. Parker, and C. L. Smith, Allison Div., General Motors Corp., Indianapolis, Ind. (1315-60)

✦Conversion System for Snap VIII, Paul Wood, et al, Aerojet-General Corp., Azusa, Calif. (1316-60)

✦H_2, O_2 Turbomachinery Power System for Space Vehicles, H. Wood and N. Morgan, Vickers, Inc., Los Angeles, Calif. (1317-60)

✦Minimum Specific Weight Space Powerplant, Edward G. Rapp, Thompson Ramo Wooldridge, Inc., Cleveland, Ohio. (1318-60)

✦A Vortex MHD Power Generator, R. Coerdt, J. McCune, and R. T. Craig, Thompson Ramo Wooldridge, Inc., Cleveland, Ohio. (1319-60)

✦Aspects of MHD Generators for Space, John Huth, The Rand Corp., Santa Monica, Calif. (1320-60)

✦Dynamic Versus Direct Conversion, Ken Johnson, Aerojet-General Nucleonics, San Ramon, Calif. (1321-60)

✦Zero-Gravity Boiling and Condensing, L. M. Hedgepeth, Wright Air Development Div., Wright-Patterson AFB, Ohio. (1322-60)

FRIDAY, SEPTEMBER 30

Systems for Nuclear Auxiliary Power

9:00 a.m. **Satellite Room**

Chairman: G. M. Anderson, Atomic Energy Commission, Washington, D.C.

Vice-Chairman: Robert English, Lewis Research Center, NASA, Cleveland, Ohio.

✦Introduction—Snap Program, G. M. Anderson, Atomic Energy Commission, Washington, D.C. (1323-60)

✦Snap II Concept, Herman M. Dieckamp, Atomics, International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1324-60)

✦Snap II Reactor Status, R. D. Keen and R. R. Eggleston, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1325-60)

✦Snap II Power Conversion Status, D. L. Southam, Thompson Ramo Wooldridge, Inc., Cleveland, Ohio, and R. L. Wallerstedt, Atomics International, Div. of North American Aviation, Inc., Cangao Park, Calif. (1326-60)

✦Snap II Radiative-Condenser Design, M. G. Coombs and R. A. Stone, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1328-60)

✦Snap II System and Vehicle Integration, Donald J. Cockeram and R. L. Wallerstedt, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1329-60)

✦Snap Thermoelectric Systems, M. G. Coombs and A. W. Thiele, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1330-60)

✦Snap VIII Reactor, C. E. Johnson, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1331-60)

✦13 Watt Iostope—Powered Thermoelectric Generators for Space and Lunar Impact Missions, Justin L. Bloom, The Martin Co., Baltimore, Md. (1332–60)

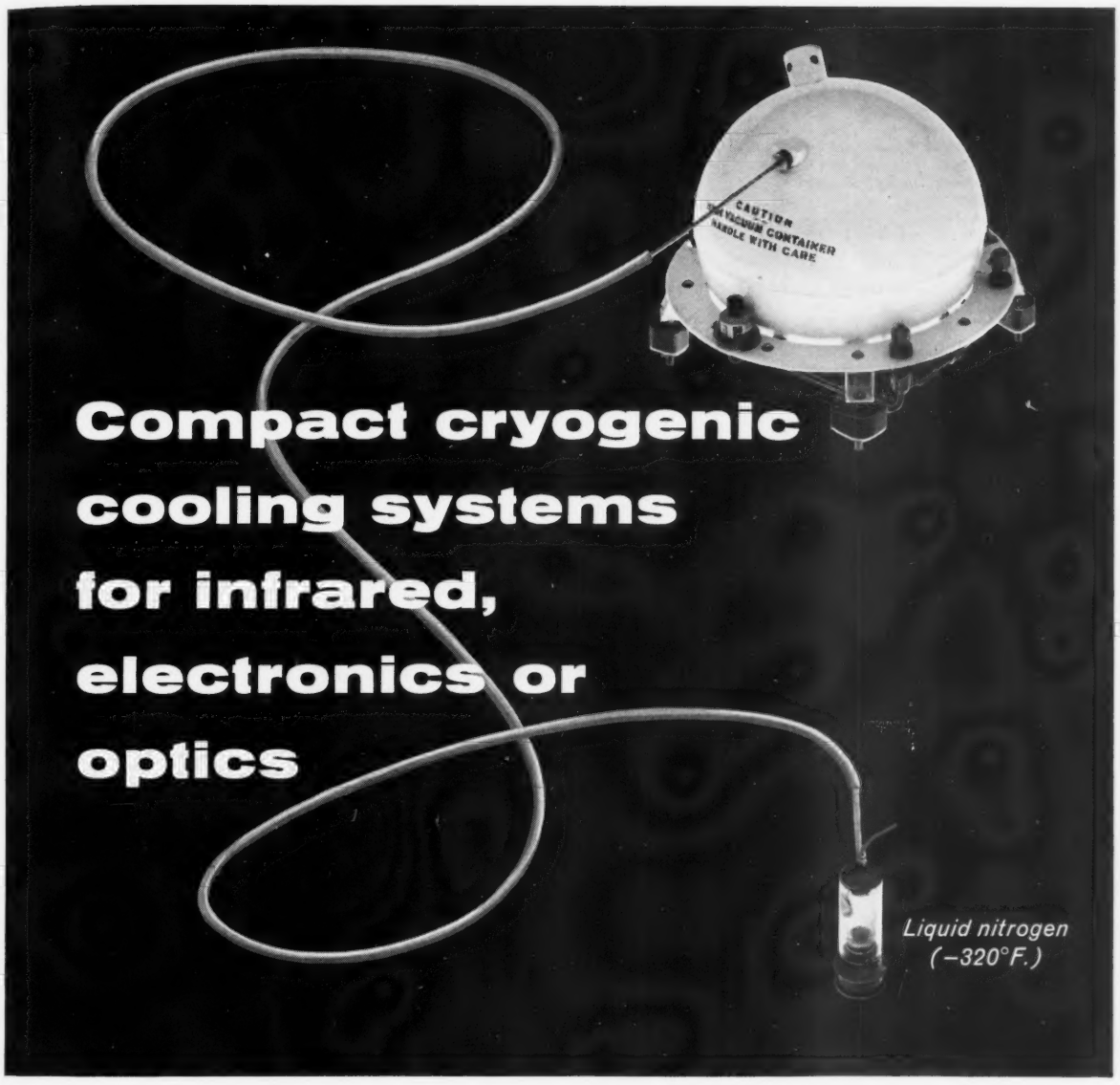
Application, Safety and Advanced Systems

2:00 p.m. **Satellite Room**

1960 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
Aug. 15–20	11th International Astronautical Congress	Stockholm, Sweden	Past
Sept. 27–30	Power Systems Conference	Santa Monica, Calif.	Past
Oct. 10–12	Human Factors and Bioastronautics Conference	Dayton, Ohio	Past
Nov. 3–4	Electrostatic Propulsion Conference	Monterey, Calif.	Aug. 5
Dec. 5–8	ARS Annual Meeting and Astronautical Exposition	Washington, D.C.	Aug. 25

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.



New AiResearch system delivers nitrogen in liquid form from storage system to cooling area

Now units requiring cryogenic cooling no longer need be designed with allowances made for bulky expanders or adjacent storage tanks.

The new AiResearch system transfers the coolant *in liquid form* to a point of use *25 feet or more away*. The liquefied gas passes through an uninsulated, small, flexible tube which can be bent over and around obstructions. Because the storage system can be placed anywhere, space limitations are overcome and vehicle installation problems are simplified.

The complete system includes the cryogenic liquid container, pressure and flow controls, the liquid transfer tube and cooling adapter. The system can be operated without external power. It can be used with missile, aircraft, space or ground based units and can be converted to a closed-cycle system with the addition of a small gas liquefier.

AiResearch has pioneered many new developments in the cryogenic field. It is presently engaged in work on systems utilizing helium, hydrogen or neon as coolants, and cryogenic systems for zero G operation.

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Chairman: G. M. Anderson, Atomic Energy Commission, Washington, D.C.

Vice-Chairman: Harold Greenfield, Lockheed Missiles and Space Div., Sunnyvale, Calif.

✦NASA's Requirements and Program for Nuclear-Power Reactors for Space Vehicles, Harold B. Finger, National Aeronautics and Space Administration, Washington, D.C. (1333-60)

✦Shield Designs of Snap Reactors, V. Keshishian, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1334-60)

✦Snap Safety Program for Space Reactor Application, F. D. Anderson and J. G. Lundholm, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1335-60)

✦Analysis of Radiological Hazards Associated with Snap Re-entry, Paul D. Cohn, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1336-60)

✦The Application of Snap Reactor Units to Current Space Vehicles, Joseph R. Wetch and J. G. Lundholm, Atomics International Div. of North American Aviation, Inc., Canoga Park, Calif. (1337-60)

✦Problems Associated with the Development of a Thermionic Conversion Reactor, R. L. Hirsch and J. W. Holland, Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. (1338-60)

✦Nuclear Reactor—Thermionic Space Power System, L. Perry, General Atomics, Div. of General Dynamics Corp., San Diego, Calif. (1339-60)

✦Boiling Versus Nonboiling in Liquid Metal Reactors David L. Cochran, Aerojet-General Nucleonics, San Ramon, Calif. (1340-60)

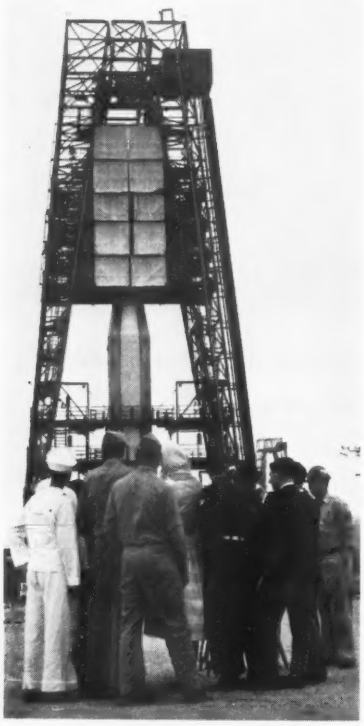
✦Safety Analysis and Tests of a Radioisotope Powered Thermoelectric Generator, Paul J. Dick, The Martin Co., Baltimore, Md. (1341-60)

200 Explorers in Phase II of Space Science Program

Two hundred amateur astronauts participated in a two-day encampment at Vandenberg AFB on June 18–19. The encampment constituted Phase II of the Explorer Space Science Program launched recently by the ARS Southern California Section with the cooperation of the Los Angeles Area Council of the Boy Scouts of America and the architect-engineering firm of Daniel, Mann, Johnson and Mendenhall.

Leaders of SAC, BMD, and the Scouts welcomed the youthful Explorers to the Base. Four 40-min seminars took place on Saturday afternoon. They were concerned with Bioastronautics, Guidance and Control, Propulsion, and Ground Support. On Sunday afternoon, two additional seminars were held.

Explorer Scouts inspect model of manned satellite station.



Teen-aged rocketry buffs inspect Atlas ICBM scheduled for launch of Samos reconnaissance satellite at Vandenberg AFB. Safety measures were stressed at Scouts' two-day encampment.

Tours of various facilities were arranged for both days. The Scouts and their guides visited Thor wet pads; a Discoverer blockhouse and pads; Point Arguello; and Samos and Midas pads.

ARS and AF members who accompanied the group were impressed by the depth of the youngsters' questions and by their obvious grasp of scientific principles.

During the encampment, plans for Phase III of the Program were presented to the group, and applications for registration were accepted. Phase III will be a Space Science Seminar consisting of 40 evening or Saturday meetings, held bi-weekly during the 1960–61 school year. Each meeting will have two parts, the first devoted to basic science and engineering, and the second to application of principles. The last five meetings will include time for the development and construction of a Seminar project.

ARS-Navy to Hold Symposium On Electrostatic Propulsion

The ARS Ion and Plasma Propulsion Committee in conjunction with the U.S. Naval Postgraduate School has announced plans to co-sponsor a specialist conference on Electrostatic Propulsion, November 3–4, in Monterey, Calif.

The conference will provide an opportunity for critical discussion among active workers in this field, within the bounds of the topics listed below. Papers on electromagnetics and arcjet propulsion will not be included.

A flyer was sent to all ARS members last month inviting contributions. Both unsolicited and invited papers will be included in the program. The entire program will be mailed next month, and will be carried in the October issue of *Astronautics*.

The topics for the conference follow.

ION GENERATION
- Thermal contact ionization
  - Fundamentals
  - Porous diffusers
  - Front feed systems
- Gaseous discharges as ion sources
- Production of heavy charged particles or charged colloids
- Production of negative ions
- Efficiency considerations
- Atom/ion ratio, theory, measurements, and techniques

ION ACCELERATION
- Ion optics
  - Analytical studies
  - Techniques and results of analogue devices
  - Experimental results using actual focusing systems
- Accelerate-decelerate systems
- Electrode interception and erosion

BEAM NEUTRALIZATION
- Relevant background
- Electron and plasma dynamics
- Neutralization by electron injection
  - Theory, in 1, 2, or 3 dimensions, transient and steady state
  - Conservative systems, involving no electron energy loss as an essential part of the process
  - Dissipative systems in which electron energy loss is essential
    - Energy loss due to gas collisions
    - Energy loss due to other processes
    - Electron dynamic and sheath interactions
  - Experiments
    - Broad beams
    - Narrow beams
  - Techniques
    - Disposal of atoms and ions from beams
- Neutralization by charge exchange
- Neutralization of bipolar ion beams
- Neutralization of heavy particle or colloid beams
- Transient and oscillatory effects
  - Noise generation

PERFORMANCE TESTING
- Diagnostic techniques
- Laboratory testing
  - Wall effects
- Testing in space
  - Necessity for full feasibility test
  - Problems

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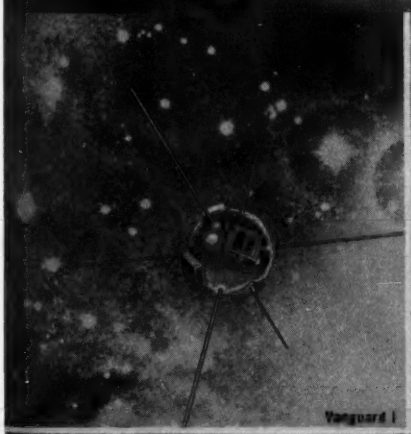

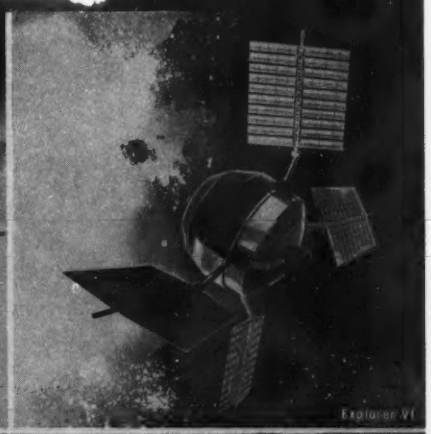

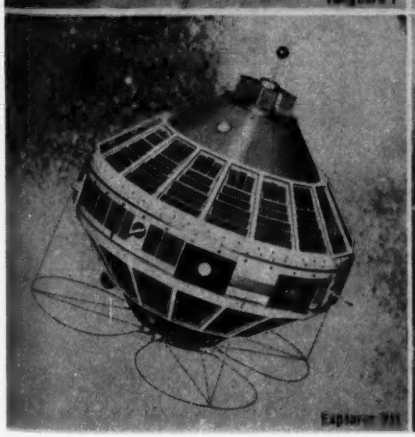

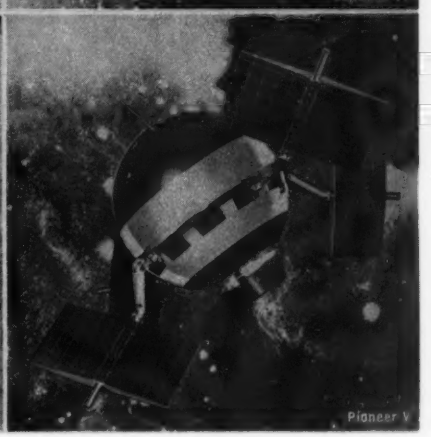

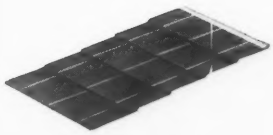

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ARS, WADD Sponsor Specialist Conference, Oct. 10–12

ARS has planned a specialist conference on Human Factors and Bioastronautics in conjunction with Wright Air Development Div. in Dayton, Ohio, Oct. 10–12.

Five sessions are scheduled for the $2^1/_2$-day meeting along with field trips to WADD and tours of the Air Museum and the Occupational Medicine Hospital. The tentative program calls for sessions on Anthropometrics, Bionics, Bioinstrumentation, Human Factors Aspects of Industrial Reliability, and a final session on Government Contract Research in the Life Sciences.

To work in as much as possible in the period without overlapping, the Human Factors and Bioastronautics Committee will start the sessions at 8:30 each morning. Thus Monday's and Tuesday's sessions will run two hours, then break for a half hour, and then be followed by second two-hour morning sessions. The Wednesday session on Contract Research will continue through the morning with an intermission at about 10:30 a.m.

Luncheons are scheduled for Monday and Tuesday, and a banquet for Tuesday evening. The afternoons will be devoted to field trips.

Gas Dynamics Volume Issued By Northwestern Univ.

A handsome, illustrated edition of the papers and lectures presented at the Proceedings of the Third Biennial Gas Dynamics Symposium, held August 24–26, 1959, under the auspices of the AMERICAN ROCKET SOCIETY and Northwestern Univ., with an introduction by Theodore von Karman, to whom this book is dedicated, is now available at a cost of $12.50.

The volume, edited by Ali Bulent Cambel and John B. Fenn, is arranged in four parts: Part 1—Elementary Processes and Properties in Ionized Gases; Part 2—Theoretical Considerations on the Interaction of Magnetic Fields and Flow of Ionized Gases; Part 3—Laboratory Experience with Ionized Gas Flow; and Part 4—Applications of Magnetogasdynamic Effects.

Gaseous Nuclear Rockets Papers Now Being Accepted

The Nuclear Propulsion Committee requests interested persons who want to present a paper on Gaseous Nuclear Rockets or related fields at an unclassified session during the ARS annual meeting in Washington, D.C., next December, to submit an abstract by August 15 to Frank Rom, NASA, Lewis Research Center, 21000 Brookpark Road, Cleveland, Ohio.

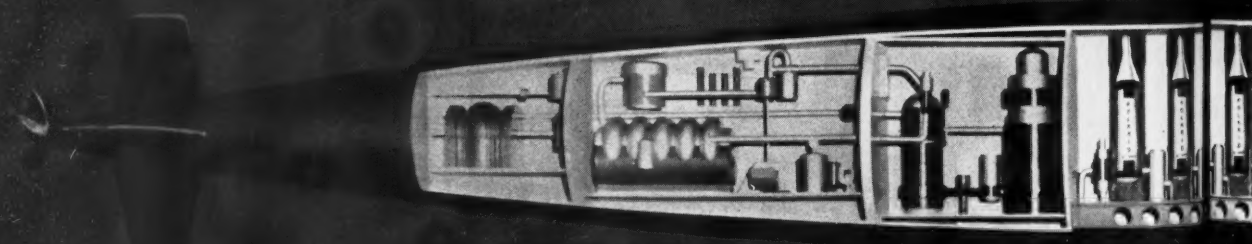
SECTION NEWS

Central Colorado: Planners of ARS meetings may want to consider the attendance obtained by the Central Colorado Section at its May meeting at the Air Force Academy. The formula that attracted one of the largest crowds in years (over 350 people) was a combination of attractions that appealed to the interests of most of the rocket men in the area. Included in the program was a chance to visit the Academy, a planetarium show, a social hour, a fine smorgasbord dinner, and a talk, with slide illustrations, by ARS Vice-President **Harold Ritchey,** vice-president of Thiokol Chemical.

Dr. Ritchey talked on solids versus liquids. Since the talk was made by a "solid" expert to a group of "liquid" men, the discussion was both interesting and spirited.

Dandridge Cole, outgoing Section president, and his officers were given a standing ovation for their year's work; and the new slate of officers, headed by president-elect Denis Zigrang, was introduced. The other new

Undersea launch pad for sixteen Polarism



officers are Bill Howell, vice-president; John Boretz, secretary; and Paul Lord, treasurer.

—Clyde Briggs

Chicago: Three score and ten members and wives attended the annual Spacetronautic Banquet in June, at the Orrington Hotel in Evanston, in honor of **Kurt R. Stehling,** deputy director of NASA'S Program Planning Group. Among the guests of honor were ARS Director and Mrs. **Ali Bulent Cambel** and **Father D. J. Roll** of Loyola Univ. who is president of the Chicago Technical Societies Council. The social hour, preceding the banquet, was provided with the compliments of the following industrial sponsors: Chicago Bridge and Iron Co., Continental Chemiste Corp., Meyercord Co., Stanway Corp., and Stewart-Warner Corp.

Introduction of guests, officers, and directors was capably handled by Dan Ljubenko, program chairman for the 1960-61 season. "The Challenge of Gibraltar" was the topic of **Chuck Miesse's** presidential address, and new officers and directors were installed by Steve Fraenkel.

The meeting then adjourned to Northwestern Univ.'s Technological Institute, where the Gas Dynamics Colloquium co-sponsored the Spacetronautic Lecture, open to the public. Introduced by Prof. Cambel, Kurt Stehling presented an informative and stimulating lecture on the NASA Mission—Atmospheric probes, instrumented satellites, manned satellites, and space probes. In response to pointed questions from the enthusiastic audience, Stehling asserted that the Soviet claim of impacting the moon was no doubt correct, and that they have definitely not put a man aboard their latest kingsize satellite, since their present tracking capabilities are inadequate for the recovery mission. The Spacetronautic Lecture was tape-recorded, and reprints will be available in the near future.

—R. Warder

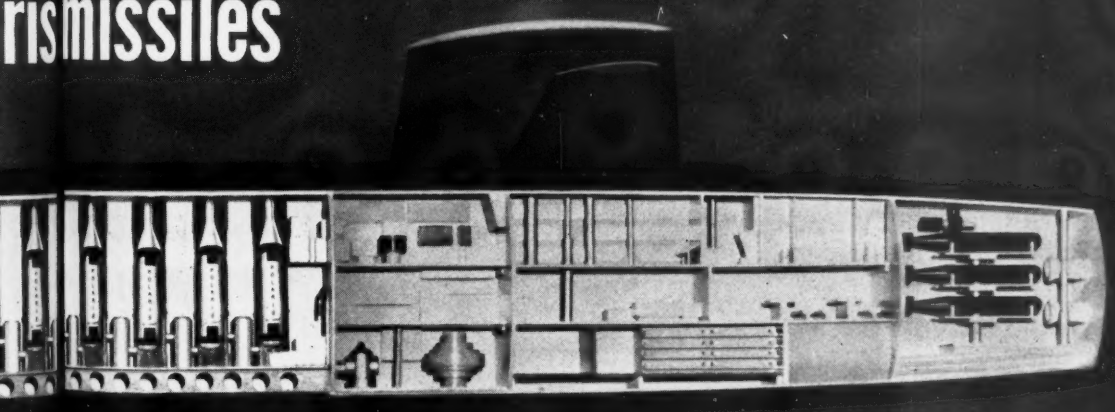
Spacetronautics at Chicago

Kurt Stehling, second from left at the head table, warms up as honored guest and speaker at the ARS Chicago Section's annual Spacetronautic Banquet. Deputy Director of NASA's Program Planning Group, Stehling discussed NASA Missions at the ensuing meeting, which was open to the public.

Columbus: The June meeting of the Section was a field trip to the plant of Herrick L. Johnston, Inc. The evening began with a tour of the plant, during which members had the opportunity to see the vacuum-insulated containers manufactured there for storing liquid hydrogen, oxygen, and nitrogen.

Following the tour, Section Vice-President Kenneth Greenlee intro-

rismissiles



A U. S. Navy Polaris submarine is a self-sufficient missile base. It provides comfortable quarters for its hundred-man crew and carries supplies for several months. In its launching tubes—eight on each side, as shown in this cutaway model—will nest 16 Polaris missiles. But a Polaris sub differs from all other missile bases in one important respect: it can disappear from the face of the earth for weeks at a time. Though its position in ocean depths will be unknown, its presence will be felt. For—should America ever be attacked—each Polaris sub could launch its 16 Polaris missiles in as many minutes. Lockheed is prime contractor and system manager for the Polaris missile.

LOCKHEED MISSILES & SPACE DIVISION SUNNYVALE, CALIFORNIA

duced **Herrick L. Johnston,** the founder of the firm. Dr. Johnston told of his work on liquid hydrogen at Ohio State Univ. in the early 1940's, when he was director of the University's cryogenics laboratory. Herrick L. Johnston, Inc. was formed in 1953 to produce liquid hydrogen, but the organization turned to the manufacture of vacuum-insulated vessels when these could not be procured for its own use. The plant is currently making hydrogen storage bottles for the first operational Hy-Lox rocket engines.

Slides of some of the products built by Herrick L. Johnston, Inc., and a movie indicating the company's part in the Centaur program were shown.

—James A. Laughrey

Connecticut Valley: The annual social dinner meeting of the Section featured a talk by **R. B. Canright,** NASA Saturn program manager, on "The Evolution of Saturn Vehicle Concepts," reviewing the early theoretical and design work of Von Braun and his co-workers on a large rocket vehicle; the influence of the Douglas Dynasoar studies; the evolution of the upper-stage concept; and the Saturn project's political problems, progression to future configurations, and the calculated risk of the final choice.

Before the dinner, the members and their wives were hosts at a party sponsored jointly by the Chandler Evans Corp.; Carl W. Lemmerman, Inc.; Olin Mathieson Chemical Corp.; Technoproducts, Inc.; and Vietco Engineering and Vietco Marine, Inc. After an excellent dinner, the members and their guests enjoyed dancing until midnight.

Maryland: At the March dinner meeting, sponsored by the Martin Co., guest speaker **Homer J. Stewart,** director of NASA's Office of Program Planning and Evaluation, addressed the Section. His talk was in two parts. Dr. Stewart first discussed the space problems as an element of the transportation business. He described the differences between rockets needed for space transportation and those needed for weapon delivery. After considering the improvements which are likely to be made in the former, and relevant economic questions, he concluded by saying that we expect to arrive at a point where the basic transportation charge for placing a spacecraft in orbit will be a relatively small fraction of the value of the spacecraft itself; that there will be a real prospect that the economic return to the country through the uses of space can compensate for the investment made; and that in limited areas of application, such as communications, we may look forward to net economic benefits. The second part was a broad description of NASA's long-range planning. This material had been presented to the Congress in January and was widely reported through the various news media. A stimulating discussion followed Dr. Stewart's presentation.

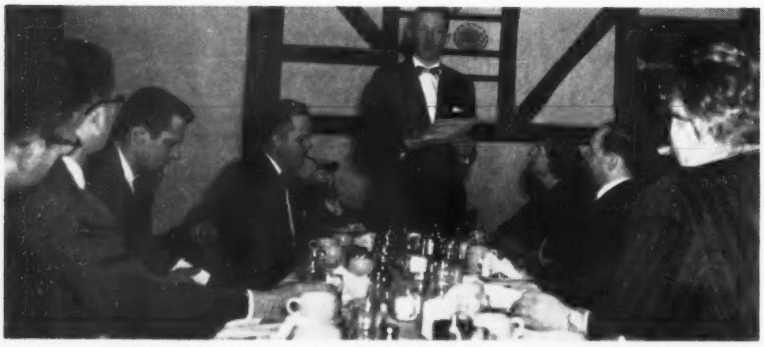
—Harold J. Hasenfus

Northeastern New York: The following officers were elected and installed at our annual meeting in May: Bruce H. Neuffer, president; Erwin Fried, vice-president; Neil E. Munch, secretary; and Robert C. Bowlin, treasurer.

—Neil E. Munch

Northern California: In June, the Section met at Hal's Restaurant for a social hour and dinner. Following the dinner, members met at the Lockheed Missiles and Space Div. auditorium in Palo Alto for a talk by ARS Director **A. K. Oppenheim** of the Univ. of California on "The Anatomy of Detonation."

Air Power for Defense



This was the title of an address recently by Gen. H. T. Markey, president of the Air Force Assn. to the Chicago Section of ARS. Above, Chicago Section president C. C. Miesse, standing, introduces Gen. Markey, at his right, to Section members.

PMR—A New Section

ARS President Howard S. Seifert presents a charter for the new Pacific Missile Range Section of the Society at a recent dinner meeting at the PMR Officers Club. From the left in the photo, Rear Adm. Jack P. Monroe, USN, commander of the Pacific Missile Range; L. E. Wood, president of the new Section; and Dr. Seifert.

The lecture described work undertaken by Dr. Oppenheim and associates on detonation waves in stoichiometric gaseous hydrogen-oxygen mixtures. Photographs of the phenomena showed that the accelerating flame piles up propellant mass in front until a detonation wave results. Other data demonstrated that the shocks from a number of flame fronts converge to yield a superdetonation whose energy gradually dissipates to the normal state. Dr. Oppenheim stated the literature shows that U.S.S.R. scientists are conducting extensive investigations in this field, but, he noted, that even small investigations are blown up by them into so-called significant papers.

—Howard M. Kindsvater

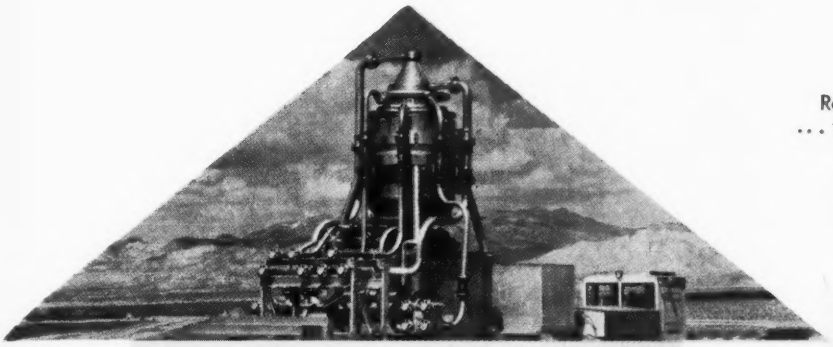
Orlando: In a May meeting, the following new officers were elected: Donald K. Robertson, president; William A. Elfers, vice-president; J. Allen, secretary; and Lucien L. Farkas, treasurer.

—John M. Allen

Princeton: In May, the Section was host to over 400 members of the New York, Philadelphia, Long Island, and Valley Forge Sections. The occasion was an open house at Princeton Univ.'s James Forrestal Research Center, featuring a look at research programs being conducted by Princeton's Aeronautical Engineering Dept.

The guests were toured in groups of 30 to 40 through **Prof. D. C. Hazen's** "smoke" tunnel, in which they saw flow-visualization techniques applied to a three-dimensional delta wing at low (takeoff) speeds; through **Prof. A. A. Nikolsky's** helicopter test

AT THE CONTROLS on three new frontiers . . .



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NUCLEONICS & INSTRUMENTATION

Plowshare...this is the program for development of peacetime uses of nuclear explosions. Measurement, timing, control and recording instrumentation by EG&G is vital to Plowshare's Project Gnome, the project for the evaluation of techniques for underground generation of nuclear power and production of isotopes for industrial use.

Vela . . . EG&G, oriented in the design, installation and operation of nuclear detection and measurement systems, is contributing its skills to this international nuclear explosions detection program.

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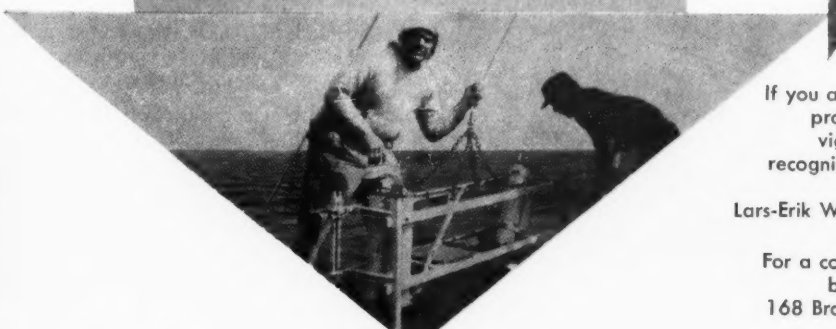

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track, in which scale models of helicopters and other VTOL craft can be flight-tested with three degrees of freedom over a 700-ft distance; through **Prof. S. M. Bogdonoff's** Gasdynamics Laboratory, where they had the opportunity to observe complete supersonic and hypersonic wind-tunnel facilities; and through **Prof. C. D. Perkins'** flight-test hangar, in which two research Navions, a Vertol helicopter, a Hiller ramjet helicopter, and several ground-effect machines were on display.

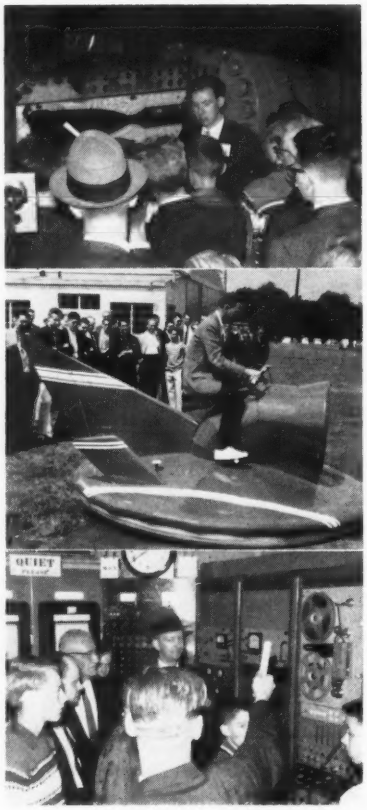
Demonstrations of the Department's 80-kw plasmajet, used to study gas-transport properties at temperatures up to 25,000 F, and **T. Sweeney's** ground effect machine provided the members a glimpse of future developments in the aerospace field. The main event of the morning was a series of rocket test runs for **Prof. L. Crocco's** rocket-combustion-instability project. Members had the opportunity to observe four tests which formed part of a survey on transverse-mode instability characteristics.

A box lunch on the hangar apron, attended by more than half the attendees, closed the formal proceedings. Members and guests were then free to examine further the Princeton campus and attend the afternoon's athletic events at their leisure.

At the regular meeting in May, the Section presented a panel discussion and film on the Tiros I satellite. Section Vice-President **Sidney Sternberg,** chief engineer of the RCA Astro-Electronic Products Div., was moderator, with technical discussions by **V. D. Landon** and **J. A. Strother** of RCA and **Rudy Stampfel** of NASA. This meeting was attended by about a hundred Princeton Section members and their guests.

—Jerry Grey

Princeton Outing



The ARS Princeton Section recently was host for a day at Princeton Univ. to over 400 members of the ARS New York, Philadelphia, Long Island, and Valley Forge Sections. Part of the day's activities included these scenes: Top, Maurice Webb describing the supersonic wind tunnel; middle, Tom Sweeney demonstrating his ground-effect machine; and Webb again reviewing the data-recording equipment of the rocket test facility.

STUDENT CHAPTERS

Missouri School of Mines: This Chapter was formed on Oct. 7, 1959. At present it has 103 members. Its meetings have featured speakers from Bell Telephone Labs, Rocketdyne, NOTS, and McDonnell Aircraft. Many programs included films on rocketry and space flight. The highlight of the year was a field trip to McDonnell Aircraft in St. Louis, which included a viewing of the Project Mercury capsule.

The following officers were elected for the 1960–'61 academic year: Milton Burford, president; Ron Brenner, vice-president; Larry G. Bauer, secretary; and Jim Walker, treasurer.

—Larry G. Bauer

Oklahoma Univ.: In an April meeting, guest **John Hrenak** of McDonnell Aircraft gave an interesting talk on "The Performance of Hypervelocity Missiles." A question-and-answer period followed the talk.

At a meeting held in May, the following new officers were elected unanimously by the membership: John K. Totten, president; Don Smith, vice-president; Mike Ruby, secretary; George Teas, treasurer; and John B. Miles, St. Pat's representative.

Then, regarding plans for next year, these three points were discussed: We should rely more on faculty speakers; arrangements should be made for industry speakers during the summer; the Aeronautical and Space Engineering school will need help next year instrumenting the rocket propulsion laboratory.

—John Totten and Mike Ruby

Univ. of Michigan: The Chapter held its last meeting of the school year in May with the student group of the IAS. We had as speaker **Hubert M. Drake,** assistant chief of the Research Div. of NASA. His subject was "Current Programs at the NASA Flight Research Center," and he spoke mainly of the X-15 tests.

May 13, 14, and 15 constituted Engineers' Weekend locally, for which the Chapter had displays in and around the Aeronautical Laboratories on North Campus. Our displays were a Nike-Ajax on loan from the Army and a Falcon missile from the AF.

—Judith M. Forde

Univ. of Virginia: At the May meeting, the following new officers were elected: G. N. Gallagher, president; Stuart Colvin, vice-president; Blake Bacon, secretary; and John Ferguson, treasurer.

—Blake Bacon

CORPORATE MEMBERS

American Bosch Arma Corp. has acquired joint ownership with De-Havilland Holdings, Ltd., of a major producer of precision navigation and gyroscopic equipment, S. G. Brown, Ltd., Watford, England . . . **Bendix Corp.** has formed Bendix Support Equipment-Teterboro (N.J.) and -South Bend (Ind.) to develop, manufacture, and sell support equipment for missiles and military and commercial aircraft. Another company, Teldix, has been set up in Heidelberg, Germany, to handle aircraft systems and equipment . . . **Burroughs Corp.** has announced the team to produce the Airborne Long Range Input system for the AF. They are Electronic Communications, A C Spark Plug, Lockheed Aircraft Service; GPL Div. of General Precision; Philco Corp., Technical Products Div. of Packard-Bell Electronics, and Military Electronic Computer Div. of Burroughs. Burroughs International, S.A., in Switzerland, has been formed as a major expansion of company operations in Western Europe.

Callery Chemical Co. plans a new R&D lab in Encino, Calif . . . Experiment, Inc., has changed its name to Texaco Experiment Incorporated . . . **Ford Motor Co.'s** new Special Military Vehicles Operations will function as a component of the Defense Products Group. Ground was recently broken for the seventh major building of Aeronutronic Div.'s new Engineering and Research Center at Newport Beach, Calif. . . . **General Dynamics** has established General Atomic Europe to be engaged in the

Three generations of ARMA computers:
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The itinerant bee has nature's simplest yet most advanced guidance system. His built-in computational abilities—certainly his miniaturization—haven't yet been approached by man.

ARMA, however, is showing the way. A six-year computer miniaturization program, completely company-funded, is producing a family of progressively smaller and more sophisticated computers for use in man-made guidance systems. Here is the result thus far in this continuing program.

Small: ARMA's operational computer, now in use in inertial guidance systems, employing all semi-conductor circuitry, printed wiring techniques and conventional logical design organization.

Smaller: a second-generation computer ...all-solid state, with no moving parts, applicable to *all* types of navigation, embodying 1/4 the volume, 1/3 the weight and 1/15 the power requirements of its predecessor.

Still Smaller: the third member of the family. This microminiature computer, to be completed in 1961 from components now in existence, will be 1/25 the volume and 1/10 the weight of the first-generation model while performing the same guidance and control computations. It will have application in missile guidance, space navigation and guidance, orbit transfer problems, submarine navigation and periscope stabilization. The reliability of this sophisticated product will be assured by thorough testing in ARMA's environmental facilities—most complete in the industry.

ARMA, Garden City, N.Y., a division of American Bosch Arma Corporation . . . supplier of precision inertial guidance systems for long range Air Force missiles . . . the future is our business.

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AMERICAN BOSCH ARMA CORPORATION

field of nuclear energy . . . The Defense Systems Dept. of **GE** has opened a Boston District office . . . **Giannini Scientific Corp.** has acquired Wiley Electronics Co. of Phoenix, Ariz., specializing in the fields of coherent radar and microwave radiometry . . . **Haveg Industries** has completed its new R&D Laboratory Facilities in Taunton, Mass.

Hughes Aircraft has purchased MevA (cq) Corp., Santa Monica, Calif., only commercial manufacturer of cyclotrons. The Ground Systems Group has opened its new computer laboratory at Fullerton. Howard Hughes doctoral fellowships in science and engineering have been awarded to two Hughes engineers and four university graduate students. Some 52 college graduates have been chosen for Hughes Master of Science fellowship grants for 1960 . . . Lockheed Electronics Co. of **Lockheed Aircraft** has decided upon the Princeton, N.J., area for its headquarters . . . Plans for development of an 80-acre plot in east Anaheim, Calif., into a large electronics complex were announced by Autonetics, a division of **North American Aviation.** Eventually, the company says, related operations at various locations in the LA area will be integrated into this facility . . . **Packard Bell Electronics Corp.** recently opened a new 53,000-sq-ft building in the company's 100-acre Electronics Park.

Raytheon has dedicated a new Airborne Equipment Center at Sudbury, Mass. The company has bought a 40 per cent interest in Selenia Spa (Industrie Elettroniche Associate) a new, large electronics company formed in conjunction with two Italian companies . . . **Sperry Rand Corp.** plans a specialized research center in Sudbury, Mass. . . . **Sundstrand Turbo Div.'s** Pacoima, Calif., facilities, personnel, and programs are being integrated into the company's Denver group . . . **Thompson Ramo Wooldridge** last month dedicated its new Colwell Engineering Center in Cleveland, Ohio. TRW announced it will manufacture and sell its RW-300 Digital Control Computer in the European market through a newly formed corporation, Compagnie Generale de Telegraphie Sans Fil (CSF), Paris. . . . **Vitro Corp. of America** has opened its new West Coast facility in Los Angeles to serve the electronics, space, weapons, chemical, and nuclear industries . . . **Westinghouse Electric** is establishing a new Astroelectronics Lab on a 50-acre site in Conejo Valley, near Los Angeles. ♦♦

Mach 20 Shock Tunnel For Republic Aviation

A combustion-driven Mach 20 shock tunnel is scheduled for completion next month at Republic Aviation as part of its new Research and Development Center. The tunnel, reportedly one of two in the country utilizing pressures to 100,000 psi, was designed and is being built and installed by Fluidyne Engineering Corp.

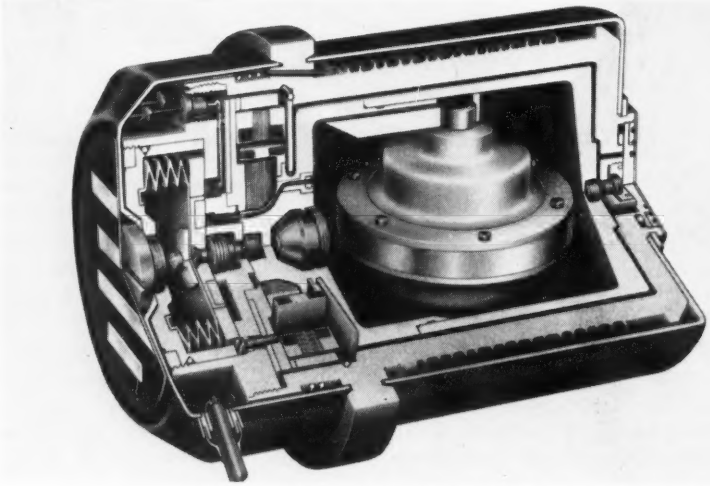
Text Now Available For Use with Edroc

A text called the "Fundamentals of Rocket Propulsion" (Reinhold Publishing) has been prepared for use with the educational rocket engine, Edroc, described in the February 1960 *Astronautics*. The Rotaug Corp. reports that Edroc has found acceptance in industry as well as schools, various companies and laboratories having ordered the $^1/_2$-lb-thrust unit for flame and combustion studies, igniter development, vernier-control experiments, etc. Inquires concerning Edroc should be directed to The Rotaug Corp., 666 Clinton Ave., Newark 8, N.J. (ESsex 2-6838).

Before the Flight

The all-inertial guidance system (inertial platform, computer, and central control) being developed by American Bosch Arma Corp. for the Atlas ballistic missile goes into an environmental chamber for an extensive series of preflight checkout tests. The Arma inertial system guided an Atlas 5000 miles down the Atlantic Missile range for the first time June 11.

M-H Ceramic Gyro



The cutaway illustrates an 8-oz, 2.8- x 2.0-in. gas-bearing gyroscope recently shown for the first time by Minneapolis-Honeywell. The bell-shaped component is a ceramic motor, the internal parts of which, suspended on a film of helium gas 25 millionths of an inch thick, spin at 24,000 rpm. The ceramic parts are fired to the hardness of sapphire and hold extremely close tolerances. M-H expects the new gyro to have immediate application in space vehicles.

Observation Satellites

(CONTINUED FROM PAGE 30)

properly of the center of the image, called "dancing"; second, there is change of shape of distortion of the image, called "pulsation"; and third, there is change of luminance of the image, called "scintillation."

These effects are due to atmospheric inhomogeneities and temperature differences, giving rise to refraction phenomena and turbulence. They appear to occur principally at two levels, near the ground and in the tropopause area near 40,000 ft. By careful and lengthy site-selection procedures, observatories can be, and are, located so as to minimize the lower-air effects. Thus, one generally finds observatories on mountains or high plateaus. But this seldom completely cures even the problems caused by lower-air turbulence, and, of course, does not ameliorate the poor seeing contributed by effects at the level of the tropopause.

The implications of the impressive volume of data at hand are twofold: (1) Photography of celestial objects from above the atmosphere will eliminate the effects of poor seeing contributed by the atmosphere; and (2) photography of the earth from a space vehicle will have as a lower limit a ground resolution of the order of a fraction of a foot. The atmospheric effects most likely to set lower limits on ground resolution achievable from space platforms will be the turbulent cells at high atmospheric altitudes, say 40,000 ft. These cells, a foot or so in diameter, move at perhaps 35 mph, and cause refractive deviations which may average 1.5 to 2 sec of arc. Thus, a lower ground resolution limit from a space vehicle will be of the order of half a foot. This limit will not be a serious factor for quite some time.

Experimental verification of the observational benefits to be expected when atmospheric effects are eliminated was dramatically shown recently in the sun photographs secured from a balloon-borne telescope. Project Stratoscope employed a special photographic telescope weighing 300 lb and photographed the sun from 82,000 ft, above about 96 per cent of the earth's atmosphere.

According to the Princeton Univ. group which conducted these important experiments, they secured the best sun photographs ever made. The telescope used had a 12-in. aperture and a theoretical resolution of about one-third of a second of arc. Many solar surface granules only 180 miles in diam were discovered. Were this area normal to the line of sight, it would subtend only 0.4 sec of arc—indicating that essentially theoretical resolution was reached.

A note on the photographic aspects of this last statement must be inserted. Throughout this paper and elsewhere, the author makes the point that combined film-lens resolution is of necessity lower than either film or lens resolution alone; yet here is an apparent contradiction. The answer to this seeming discrepancy comes from a detailed analysis of the actual techniques employed in the sun photography. The lens aperture was 1 ft, but the effective focal length was 200 ft (one doesn't need a fast lens to photograph the sun!). Thus the theoretical resolution of this lens system, expressed in lines per millimeter in the focal plane, is about 7–8 lines/millimeter! One would have to go to considerable difficulty to make a photographic emulsion which could degrade this already low optical resolution. By the simple formula given earlier for combining resolving powers of film and lens, the combination of 7 lines/millimeter from the lens, with, say, 100 lines/millimeter from the film, would yield a combined resolution of 6.6 lines/millimeter!

Things to Come

Better resolution is expected to be obtained with a 36-in.-diam telescope, which, according to the Princeton group, is planned for the next phase. This instrument is expected to help in analysis of the atmospheres of Venus and Jupiter, to photograph more distinctly the structure of Saturn's rings, to measure the diameter of Pluto, and to help in other important areas. Instruments such as these, and the experience gained in using them, are the logical precursors of successful use of telescopes in satellites.

Many contributions to astronomy and astrophysics are sure to be made by satellite-borne instruments: Spectro-reconnaissance of the stars, cosmic ray measurements, far-infrared brightness of space, radioastronomy measurements, etc. The "Space Handbook" contains a highly readable discussion of these matters. From the more limited interests and viewpoints of this paper, the emphasis of which is on systems that make pictures or secure essential pictorial information, the atmosphere does more than limit resolution. It blocks much of the infrared and all of the ultraviolet spectrum.

Better, and continuous, photography of the sun will help increase our knowledge of stellar evolution, heat-transport mechanisms in the sun, and sunspot mechanisms. Narrowband ultraviolet mapping of the sun would help resolve fundamental questions about the hot

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outermost layer of the sun. Photographs of space in the far ultraviolet would help answer questions about the possible presence of large clouds, invisible from earth, which radiate in the ultraviolet.

A system for securing close-up photography of the moon is described in detail in G. C. Brock's book on air photography, and is applicable to photography of that side of the moon as yet unseen by man. Such photography, of course, requires trajectories which bring the instrumented payload around the moon, and hence are not the satellite orbits otherwise discussed in this report.

The first space photographs of the planets will probably be taken from earth satellites, to be followed by space probes which carry instrumentation to the vicinity of these planets. The advent and suitable employment of propulsion systems which can put very heavy payloads into orbit around the earth—or necessarily smaller payloads much farther out into space—will make such tasks easier.

The enormous advantages in getting close to the objects being photographed are shown in the moon photo on page 31, taken from the Brock book. Showing the region of Clavius, and taken by the 200-in. telescope on Mt. Palomar, it is considered one of the finest photographs ever made. Ground resolution shown is about 1 mile, typical of the best lunar photographs taken from earth. In an effort to show how little lunar detail we can see in such photographs, despite their manifest high quality, a photograph of Washington, D.C., was systematically degraded to show ground resolutions of 200, 1000, and 5000 ft. Note the low-level detail in the photograph of Washington at the 1000-ft resolution level, which is five times better than the "sharp" moon photograph, and the complete absence of detail at the 5000-ft resolution level.

A brief examination of possible uses of observation of the earth from satellites must rest on either an extension of functions and purposes served by high-altitude aerial photography or on the discovery of new and unique observation opportunities characteristic of the satellite system itself.

The rapid development and application of aerial photography to exploration, earth sciences, land-use planning, and crop, soil, and forest inventories is well-documented. *Photogrammetric Engineering*, technical publication of the American Society of Photogrammetry, furnishes impressive and continuing evidence of the varied applications of aerial photography to the peaceful and civil activities of modern society.

Ecology, geology, geography, physiography and geomorphology and hydrography are some of the fields represented in an extensive bibliography prepared by the Library of Congress. Further details may be found in the references.

Studies of natural resources and their inventories, urban-area analysis and planning, and archeology can be assisted by data secured from observation satellites. The Gutkind and De Lause references are two unusual and beautiful books combining selected and highly instructive examples of aerial photography, and illustrate many of the points made in this brief section.

Successful application of aerial photography to the varied fields noted above depends first upon the large view afforded, which is a match to the extent of the earth phenomena and forms represented in each of the sciences, and second on the recording of fine enough detail to permit accurate identification, measurement, and comparison.

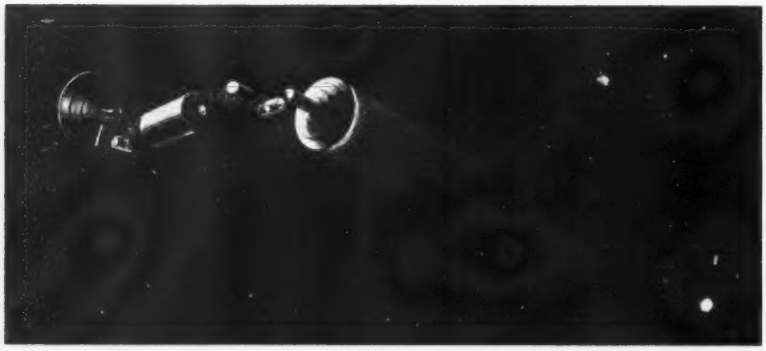
Grand View

Satellites will yield a grander view, a larger perspective than we have ever attained before. Photographs from rockets at altitudes of 150 miles have already yielded spectacular views. The possibility of seeing, as a whole, relationships, formations, and terrain features which require the perspective of distance, is an exciting prospect. The world today is still poorly mapped, its resources and far reaches still not measured.

At least several novel applications of observation satellites can be foreseen. Ice and snow surveys over vast areas, iceberg patrol, and studies of ocean wave propagation—all require the coverage of large areas, impossible to accomplish by means of conventional airborne observation systems.

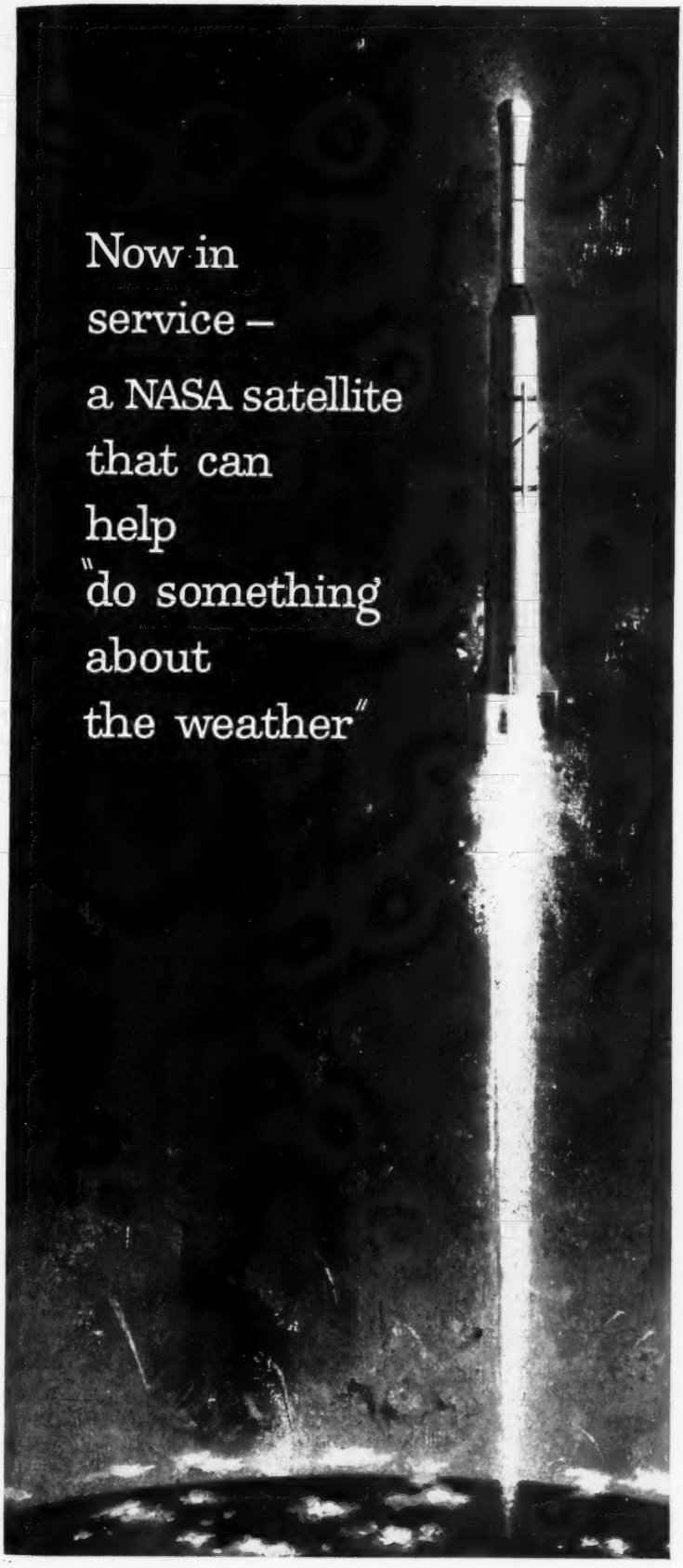
Consider this interesting example. Commission VII of the International Society of Photogrammetry is concerned with photo interpretation. One working group of this Commission, devoted to Interpretation of Ice, is made up of scientists from many countries. Subjects under investigation include Arctic ice-islands, and ice and shipping conditions in the Northwest passage, in waters north of Alaska, and along the northern sea route. Work on Antarctic ice interpretation is proceeding. At a conference on Arctic sea-ice held under the sponsorship of the National Academy of Sciences-National Research Council in February 1958, papers were presented on the distribution and character of sea-ice; physics and mechanics of sea-ice formation, growth, and disintegration; and drift and reformation of sea-ice.

This particular example of the probable applicability of observation satellite techniques to studies of sea-ice was expanded upon only to demonstrate the fact that there are groups with existing problems in areas that may seem, at first sight, remote and contrived.



Light Talk for Space

The sketch shows the concept of a sunlight space-communications system under development by Electro-Optical Systems Inc. for the Air Force. The mirror at left collects solar radiation, which funnels through a modulator at the center for coding, and then re-emits from the transmitting mirror system at the right. A nominal performance for such a system transmitting over a range of 10 million miles by 1-sq-m mirrors with 10-cps bandwidths would be a 10-db signal-to-noise ratio. EOS engineers believe this can be improved by better than a factor of 10.



Out of Space Age achievements by Government and Industry will come better living for everyone

Someday soon the art of weather forecasting will become more precise as the result of a network of meteorological satellites. Even weather *control* may become possible.

The first of these satellites, *Tiros I*, is already transmitting pictures of weather around the world. The booster that helped put it in orbit was a modified version of the reliable Douglas *Thor* IRBM. *Thor* is prime booster in the scientific "Discoverer" firings . . . has worked perfectly in over 85% of its space missions.

Thus the knowledge gained through the development of missiles has a useful peaceful application through NASA projects.

Thor is one more proof that Douglas' extensive experience in missiles is a national asset, and that nothing can substitute for the imagination, experience and skills which Douglas has accumulated in nearly 20 years of missile development.

TIROS (Television Infrared Observation Satellites) would serve weather observers—relaying information on cloud cover, temperatures, solar radiation

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Stratoscope-II Eye

A technician checks the optical surface of a 450-lb fuzed silica mirror blank produced by Corning Glass for the Stratoscope-II telescope, now being prepared by Perkin-Elmer Corp. under the direction of Princeton's Martin Schwarzschild, director of the over-all project. Balloon-borne to an altitude of some 80,000 ft, the Stratoscope-II telescope, anticipating satellite observatories, should provide information on the atmospheres of Venus and Jupiter, the nature of Saturn's rings, the formation of new stars in the Great Nebula of Orion, etc. The first Stratoscope-II flight is scheduled for some time in 1961.

The emergence and use of such a radically new tool as observation satellites will undoubtedly result in the development of applications and techniques not yet imagined or foreseeable. What is reasonably sure is that these applications will emerge.

A fundamental question relating to satellite use in the scientific fields briefly listed is whether sufficient detail can be recorded. The answer to this is an almost unequivocal "yes." By and large, if sufficient detail can be recorded for detailed observation and inspection operations, and for mapping, sufficient detail can be recorded for many earth-science studies.

One problem which has not yet received sufficient attention is that of producing accurate maps from satellites. It is now possible to sketch out briefly the nature of a mapping satellite system and its likely required components.

The problem of mapping is radically different from most other kinds of observation problems. Mapping is largely concerned with the geometric relationships between points — distances, azimuths, elevations. The aim of mapping is to produce a high-fidelity record of these data in a form tailored to the use of data. Clearly, for some applications, distance and azimuth are sufficient to define the relationship of two points. For other problems or applications, the entire profile between two points must be given.

Photographs made for observation or inspection purposes can, and frequently do, have geometric distortion *in grosso*, while showing exquisite detail at any given point.

Because of these distinctions, the use of the same parameters and indices of quality for both mapping and observation must be examined for validity and relevance. Ground resolution, however calculated, is an over-conservative statistic of the performance of a mapping system. As a suggested insight into the nature of the problems and solutions, we may consider the following. For a photographic system designed to map the earth with geometric accuracy, distortionless "hard photography" is mandatory. While, in principle, the distortions arising from photography secured sequentially, as in panoramic or strip-type cameras, or the much smaller distortions arising from use of focal-plane shutters, can be "handled" by very clever analysis systems on the ground, there is no question that this is doing it the hard way.

The solution which mapmakers have always required is to secure wide-angle photography with a highly corrected, essentially distortionless lens, the entire photography being taken simultaneously (that is, with a between-lens shutter) instead of sequentially as with focal-plane shutters, strip photography, and panoramic photography. Extremely good wide-angle optical designs are now available. Distortionless optics capable of at least 50 lines/millimeter film over the entire field are available.

Calculated ground resolution for the case of a 6-in. mapping lens at 4000 miles altitude and 50 lines/millimeter yields a ground resolution of about 2500 ft. (These numbers are not necessarily recommended numbers for either focal length or altitude, but are the shortest focal length and greatest distance which might be considered for this application.) Now, 2500-ft ground resolution might indicate to the lay observer that this is somehow the limit of our ability to measure the distance between two points. This is not true. It is well known to astronomers that distances between two blur circles can be measured to a small percentage of the blur-circle diameter, if the best modern practice is used—that is, techniques employed by careful workers in astronomy. It may be assumed that the distance between two points may be measured on a photographic plate to perhaps better than 10 times the threshold which would be indicated by the resolution calculations made above. For this extreme case—4000 miles and a 6-in. lens—this would indicate the possibility of achieving 250 ft.

Problems

There are many other problems associated with mapping. In particular, the use of film instead of glass plates (as would be necessary in satellites) imposes the requirement for emplacing accurate registration marks in the form of a carefully calculated *reseau* or fine grid on the plate. Fiducial marks along the edges of the format are also necessary. It is felt that techniques such as these, employed with care and thought (preferably applied in advance of the operation), can yield precision measures.

Measurements to 2 sec of arc seem to be within the present state of the art, and correspond to the precision

There've been some

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Bell Helicopter Company, (Formerly Bell Helicopter Corporation) Fort Worth. Texas, pioneer developer and one of the world's largest producers of rotary wing aircraft.

Hydraulic Research and Manufacturing Company, Burbank, California, outstanding designer and builder of electro-hydraulic servo control systems and valves for advanced aircraft, missiles and satellite projects.

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which can undoubtedly be achieved by careful handling.

These numbers can be used to traverse the scales of altitudes and focal length. For example, coming in to an altitude of 1000 miles with a 6-in. lens gives numbers four times better than those given above. Coming in to 1000 miles with a 12-in. lens (not unreasonable for a mapping satellite), gives numbers twice as good as these, or eight times better than the numbers calculated for the 4000-mile 6-in. combination. Thus, in principle, we could measure to perhaps 30 ft.

The speed in orbit of a satellite at 300-mile altitude is about 25,000 fps. An exposure time of $^1/_{500}$ sec implies a maximum blur corresponding to 50 ft on the ground. For sensitometric reasons, this blur will show up as about 25 ft. At much greater altitudes, the orbital speed is even less. This amount of blur could be ignored or, alternatively, a very simple and fixed amount of image motion compensation can be applied to the film during the exposure.

The flat-earth approximation would yield a ground coverage for the conventional mapping angle of 76 deg fore and aft, or one and one-half times the altitude. Since the earth is curved, the coverage is in excess of this. It would not take very many pictures from altitudes of 1000 miles or more to map the earth successfully.

To recapitulate: A 12-in. lens at 1000 miles yielding 50 lines/millimeter would give a ground resolution of about 300 ft with a measuring ability perhaps 10 per cent of that, or say 30 ft. The precision of these numbers is not critical. What is important is to recognize that we can measure distances with accuracy greater, by about an order of magnitude, than that specified by the resolution limit as calculated above. What is also important is to realize that excellent modern wide-angle optics are indeed available.

Now let us look at the characteristics of such a system. A mapping satellite would presumably require a stable table, that is, a platform stabilized with respect to the horizons. It would require recovery. It is mandatory to return a precision photograph directly for examination to avoid possible geometric degradation via the sequential transmissions from an electronic relay station. Auxiliary ground-tracking stations, and perhaps visual and electronic beacons aboard the satellite may be required to locate the satellite precisely. Star photography for precise determination of the satellite attitude at moments of terrain exposure may be required.

In general, the fewer photographs which have to be tied together to map a given area, the better mapmakers like it. Problems of bridging are minimized, and the geometry is stronger.

Thus the problem given here is not one of producing high-resolution photographs, but rather of getting high enough to produce a few photographs with adequate resolution. Clearly, with mapping lenses capable of covering an area 1500 x 1500 miles from 1000 miles in a single photograph, there will be few areas to be mapped that do not contain a number of known and recognizable control points. A system that can cover, in one photo, an area which is more than two-thirds the area of the midcontinental 48 states of the U.S. can photograph the entire world with a modest number of shots, even allowing considerable (and necessary) overlap between photographs. If a given photographic sequence starts in an area which is mapped, or has a sufficient number of recognizable control points, map extension to new areas is essentially straightforward.

Other mapping configurations are possible, such as the three-camera trimet arrangements, the two-camera twin-plex, etc.

The suggestions given above for use of ground tracking, visual and electronic beacons, star photography, and the like, contain elements of redundancy. This is desirable. Mapmakers are seldom confronted with the problem of too much good data. This embarrassment of riches should be easily handled and should result in penalties far less severe than those incurred by lack, for whatever reason, of vital data.

Although the various and separate land masses are, in part at least, fairly well surveyed with respect to individual data, these data are not yet well connected. For example, it appears that within either North America or Europe, distances of several thousand miles are known to 75 feet; the relation between the two continents is known to, say, 2000 ft. Islands may be out of position by a mile or more.

The mapping satellite will help solve this problem. So will special satellites optimized for the purpose of being observable, both electronically and visually. This may have to be a large, heavy satellite to minimize perturbations caused by drag. Alternatively, it may carry illumination sources to help increase its visibility.

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Part 5 of this series will deal with the photographic aspects of meteorological observation from satellites, and with reconnaissance satellites and inspection. Look for it in the September *Astronautics*.

Gas Generators For Tartar and Terrier

Shown being capped is one of the pair of solid-propellant gas generators used in the Tartar and Terrier missiles to power electrical and hydraulic steam turbines. Developed by Rocketdyne's Solid Propulsion Operations. The fast-burning starter boosts the electrical turbine to rated output in 0.5 sec and the hydraulic turbine to rated speed within 1 sec.

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ASTRONAUTICS Data Sheet — *Propellants*

Compiled by Stanley Sarner, *Flight Propulsion Laboratory Dept., General Electric Co., Cincinnati 15, Ohio*

AMMONIA (NH_3)

Ammonia is a colorless compound with an intensely pungent odor. Its high critical temperature allows it to be used at ambient temperatures, but its low density is highly detrimental. It is an excellent solvent and may find use in this manner in combination with high-energy solid fuels.

Hazards

Ammonia does not present much of a fire or explosion hazard. It is flammable in limited concentrations (about 16–25 per cent at ambient conditions) but must be ignited. It may form explosive mixtures with oxidizers.

The fuel is not particularly toxic. Maximum allowable concentration in air for an 8-hr day is 100 ppm. Concentrations of 400–700 ppm cause immediate irritation of the eyes, nose, and throat, while concentrations above 1000 ppm are fatal in a short time (less than $^1/_2$ hr). Concentrations of 10,000 ppm (1 per cent) are mildly irritating to moist skin, while 3 per cent will cause chemical burns. Due to the strong odor, it is unlikely that dangerous exposure to NH_3 will result unwittingly.

Parts of the body exposed to ammonia should be washed promptly with copious amounts of water, possibly supplemented with a dilute acid such as vinegar. Medical attention should follow any exposure. Boots and gloves of natural or synthetic rubber, aprons of rubber or plastic, clothing of cotton rather than wool, and goggles or full face masks should be worn. Up to 3 per cent (30,000 ppm) concentrations, the Bureau of Mines ammonia gas mask is satisfactory. Above that concentration, a self-supplying respirator is required.

Materials for Handling

Moist ammonia will not corrode iron, steel, or aluminum but will react rapidly with copper, brass, zinc, and many alloys. Steels are preferred for containers. Galvanized piping should never be used. Metals which show less than 2 mils/yr corrosion rate to anhydrous ammonia at ambient temperatures include cast iron, Ni resist, 12 Cr steel, 17 Cr steel, Worthite, Durimet 20, 18-8 stainless steel, monel, nickel, inconel, Hastelloys, aluminum, gold, platinum, tantalum, titanium, and zirconium. Suitable nonmetals include Teflon, Kel-F, pure asbestos (free of grease and graphite), glass, rubber, and some plastics.

Cost and Availability

Ammonia is readily available from a number of suppliers in tank car quantities. The annual domestic production exceeds three million tons. The current price in large quantities is about $90.00/ton.

Physical Properties of NH_3

Boiling Point		−33.38 C	−28.08 F
Freezing Point		−77.76 C	−107.97 F
Critical Temperature		132.3 C	270.1 F
Critical Pressure		111.3 atm	1636 psia
Liquid Density	at 0 C (32 F)	0.6386 g/cm³	39.87 lb/ft³
	at 25 C (77 F)	0.6029 g/cm³	37.64 lb/ft³
	at 50 C (122 F)	0.5629 g/cm³	35.14 lb/ft³
Vapor Pressure	at −3 C (25.31 F)	3.759 atm	55.248 psia
	at 27 C (79.31 F)	10.469 atm	153.86 psia
	at 47 C (115.31 F)	18.458 atm	271.26 psia
Viscosity (liquid)	at 0 C (32 F)	0.169 centipoise	—
	at 25 C (77 F)	0.136 centipoise	—
	at 50 C (122 F)	0.125 centipoise	—
Thermal Conductivity from 5 to 86 F		—	0.29 Btu/ft-hr-F

Chemical Properties of NH_3

Heat of Formation (liquid) at 25 C	−11.869 kcal/mole
Heat of Formation (gas) at 25 C	−11.04 kcal/mole
Heat of Vaporization at Boiling Point	5.581 kcal/mole
at 25 C	0.829 kcal/mole
Heat of Fusion at Freezing Point	1.351 kcal/mole
Heat Capacity at 25 C	19.36 cal/mole-C
Maximum Allowable Concentration (in air for 8-hr day)	100 ppm

Theoretical Performance of NH_3*

Oxidizer	Specific Impulse (sec) Frozen Flow	Specific Impulse (sec) Equilibrium Flow	Chamber Temperature Deg K**
O_2	285	294	3089
O_3	302	315	3350
F_2	330	357	4541
IRFNA	256	265	2700
N_2O_4	263	268	2892
ClF_3	267	280	3600

* P_c = 1000 psia; P_e = 14.7 psia; Optimum O/F ratio.

** Corresponds to equilibrium flow impulse.

In print

Physics and Medicine of the Atmosphere and Space, edited by Maj. Gen. Otis O. Benson Jr. and Hubertus Strughold, John Wiley, New York, 1960, 645 pp., illustrated. $12.50.

This book is a record of the "Second International Symposium on Physics and Medicine of the Atmosphere and Space," held in San Antonio, Tex., Nov. 10–12, 1958, and sponsored by the AF School of Aviation Medicine, and arranged by the Southwest Research Institute. It contains 42 papers presented at the symposium. The book is an excellent follow-on, rather than replacement, for the first symposium. In the second symposium, there was again a successful bringing together of physical scientists and engineers with life scientists, which resulted in the assembly of much pertinent data to manned space flight, and the cross-fertilization of the various scientific disciplines involved therein.

The book begins with several papers on the space and upper-atmosphere environment. The papers by Van Allen and Singer on the radiation environment and the one by Whipple on meteoritic material in space are especially good. The next three papers, by Schaeffer, Eugster, and Tobias with their co-authors, discuss the effects of radiation and the radiobiological implications.

The next group discusses the various rocket-propulsion and vehicle systems, and includes papers by Gen. Schriever, BIS Chairman L. R. Sheppard, Wernher von Braun, Krafft Ehricke, and others. The next several papers discuss the manned aspects of space flight, including discussions of sealed cabins, psychological problems, biomedical aspects of nuclear propulsion and of orbital flight, etc.

The next group of five papers discusses the survival in space, highlighting the problems of escape and rescue. The next three papers will be of extreme interest to the biological scientists. These include the physics of the sun by Roberts, the environments of the moon and the planets by Kuiper, and the physical environment on Mars by De Vaucouleurs.

The last two chapters are a fitting close to the record of this symposium. The first is by George P. Sutton, and is entitled "Interplanetary Travel from the Viewpoint of the Engineer," and the second by Hubertus Strughold, entitled "Interplanetary Space Flight from the Viewpoint of the Physician."

This book, in addition to its many fine papers, includes numerous references, and should find a welcome place on the astronautics bookshelf.

—**Eugene B. Konecci**
Douglas Aircraft Co.

Rocket Propellant Handbook by Boris Kit and Douglas S. Evered, Macmillan Co., New York, 1960, 354 pp. $12.50.

It is surprising that it took so long for a reference work of this type to be published. Boris Kit, head of the

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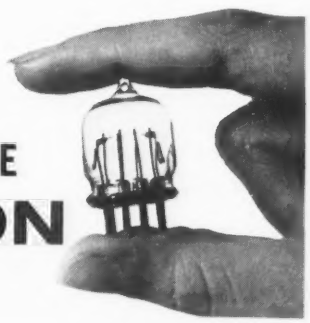

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physics and chemistry program of the Air Information Div. of the Library of Congress, and Douglas Evered of Hughes Aircraft have performed a valuable service in putting it together.

Nearly 100 chemicals with potential use as rocket propellants are described and analyzed from the standpoint of general characteristics, physical and chemical properties, methods of storage and handling, production, availability and cost, and performance. Each entry includes tables providing data on heat value, density, specific impulse, and performance with various oxidizers or fuels.

The format employed is very similar to that in the Propellant Data Sheets which have been running in *Astronautics* for the past year.

The book opens with a brief introductory section on fundamentals of rocket propellants, providing some general principles and classifications and proceeding to rundowns on liquid and solid propellants. The second section covers inorganic propellants: Aluminum, ammonia, beryllium, boron and boron compounds, fluorine and related compounds, hydrazine and hydrazine hydrate, hydrogen, hydrogen peroxide, lithium and lithium hydride, mixed acid, inorganic nitrates, nitric acid, nitrogen oxides, oxygen and ozone, perchlorates, and water.

The third section, devoted to organic propellants, covers alcohols and ethers, amines, aromatic hydrocarbons. metal organic compounds, nitroparaffins, organic nitrates, petroleum fractions, polymers, saturated hydrocarbons, unsaturated hydrocarbons, and some miscellaneous propellants in this category. A brief closing section covers pressurizing gases. Definitions, propellant data tables, and conversion factors are given in three appendices.

While the price seems a bit steep, anyone searching for a handy unclassified work on fuels, oxidizers, and monopropellants will find this new book a valuable addition to a reference library.

—Irwin Hersey

BOOK NOTES

"The Other Side of the Moon" (Pergamon Press, 36 pp., $2.50) is a translation by J. B. Sykes of the quickie publishing effort of the Soviet Academy of Sciences after the successful Lunik III shot, which was distributed by members of the Russian delegation to the ARS Annual Meeting in Washington last November. Decked out in a horribly garish cover, this slim volume makes a nice souvenir, but contributes little in the way of information which has not previously appeared elsewhere in much greater detail.

Where You Are, For Earth and Space

Engineers demonstrate the idea of a new airborne navigation system being developed by the IBM Federal Systems Div. Optics project a detailed map, representing an area 400 miles in diam, from a glass hemisphere onto a 7.7-in.-sq flat screen, and there give the viewer his exact position by means of cross-hairs. A computer provides positioning data. In space applications the glass hemisphere would carry a stellar map.

The Japanese Rocket Society has just issued the **Proceedings of its First Symposium on Rockets and Astronautics,** held in Tokyo in 1959. The Proceeding (paper covers, 393 pp., $5.00, including postage) may be obtained by writing to the JRS in Tokyo. Included are some 59 papers, primarily by Japanese authors, grouped into eight chapters, dealing with propellants, rocket motors, vehicles, satellites and space probes, instrumentation, space science, biology, and miscellaneous subjects. Several American papers, by Stuhlinger, Miele, J. Armstrong, Roberson, A. R. Hibbs, and J. E. Froelich, among others, are also included.

Moon Maps by H. P. Wilkins (Macmillan, New York, $6.00) presents a very detailed map of the moon, on a scale of 55.4 miles to the inch, in the form of a series of sturdily bound charts well-suited for use at the telescope. The text contains every named formation in alphabetical order, and the book is so designed that any chart can be placed flat next to any page of text. This looks like a valuable working guide for both amateurs and professionals.

RECEIVED

Directory of Missiles, Rockets, and Space Vehicles (45 pp., Federal Procurement Publications, Inc., 10–42 47th Rd., Long Island City 1, N. Y.). A competent review of projects and contractors; softbound.

The Universe of Light by Sir William Bragg (283 pp., Dover Publication, Inc., 180 Varick St., N. Y., N. Y., $1.85). Softbound.

Proceedings of the 1960 Heat Transfer and Fluid Mechanics Institute, held at Stanford Univ. June 15–17, edited by D. M. Mason, W. C. Reynolds, W. G. Vincenti (259 pp., Stanford Univ. Press, Stanford, Calif., $8.75). Softbound.

Structural Mechanics by Samuel T. Carpenter (538 pp., John Wiley & Sons, Inc., 440 Park Avenue South, N. Y., N. Y., $9.50). Advanced version. Hardbound.

Statistical Handbook of Science Education, NSF-60-13 (94 pp., Supt. of Documents, U. S. Govt. Printing Office, Washington 25, D. C., 0.55¢). Softbound.

Radiative Transfer by S. Chandrasekhar (393 pp., Dover Publications, Inc., 180 Varick St., N. Y., N. Y., $2.25). Softbound.

Theory of Flight by Richard Von Mises (629 pp., Dover Publications, Inc., 180 Varick St., N. Y., N. Y., $2.85). Softbound.

Theory of Wing Sections by Ira H. Abbott and Albert E. Von Doenhoff (693 pp., Dover Publications, Inc., 180 Varick St., N. Y., N. Y., $2.95). Softbound.

A Treatise on Gyrostatics and Rotational Motion, Theory and Application, by Andrew Gray (530 pp., Dover Publications, Inc., 180 Varick St., N. Y., N. Y., $2.75). Softbound.

Mechanics of Materials by Archie Higdon, Edward H. Ohlsen, William B. Stiles (502 pp., John Wiley & Sons, Inc., 440 Park Avenue South, N. Y., N. Y., $7.75). Hardbound.

Scientists in Government by Earl W. Lindveit (84 pp., Public Affairs Press, 419 New Jersey Ave., S.E., Washington 3, D. C., $3.25). Hardbound.

Selected Semiconductor Circuits Handbook. Editor: Seymour Schwartz. Co-authors: Robert E. McMahon, Arthur W. Carlson, Carl R. Hurtig, William F. Santelmann, Jr., H. C. Lin, Peter G. Sulzer, Richard R. MacMillan, and Robert Smyth (John Wiley & Sons, Inc., 440 Fourth Ave., N. Y., N. Y., $12.00). Hardbound.

Photoconductivity Solids by Richard H. Bube (461 pp., John Wiley & Sons, Inc., 440 Fourth Ave., N. Y., N. Y., $14.75). Hardbound.

Corrosion Data Survey, compiled by George A. Nelson (Shell Development Co., Emeryville Research Center, Emeryville, Calif., $50.00). New edition of reference work.

New Plastic Materials Through Government Research, PB 161332 (98 pp., Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C., $2.25). ♦♦

NAS Space Board Issues Reports

The Space Science Board of the National Academy of Sciences has issued a nine-chapter tutorial review covering the moon, planets, the nature of gravitation, physics of fields and particles, etc. The review is directed to the educated layman. Individual chapters ($1.00 each) and sets are available from PPO, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington 25, D.C.

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People in the news

APPOINTMENTS

Thomas L. K. Smull has been appointed director of NASA's Office of Research Grants and Contracts, succeeding **Lloyd A. Wood** who has been named scientist for advanced technology in the Office of Program Planning and Evaluation. **Shelby Thompson** will head the newly formed Office of Technical Information and Educational Programs.

AMC has named **Brig. Gen. Francis C. Gideon** to head its new headquarters Directorate of Data Systems. **Col. Howard B. Seim Jr.** is deputy director.

NSF has announced the appointment of **Walter Orr Roberts,** director of the Univ. of Colorado High-Altitude Observatory and professor and head of the Dept. of Astro-Geophysics, as director of a national center of atmospheric research, which will consist of a central scientific group to stimulate and supplement university research. The Foundation also appointed **Nicholas U. Mayall** director of its Kitt Peak National Observatory, new research center for optical astronomy.

Lt. Col. Allman T. Culbertson, deputy commander of the AF Missile Development Center and a member of the ARS Holloman Section, has been promoted to brigadier general.

Lt. Col. William Leonhard, AF Ballistic Missile Div. deputy commander, facilities, has been promoted to brigadier general.

Brig. Gen. Richard D. Curtin has been reassigned to USAF Headquarters where he will be deputy director of systems development in the office of the DCS/Development. Gen. Curtin was recently promoted to his new rank.

Cledo Brunetti, vice-president and general manager of Grand Central Rocket Co., and an ARS member, has been elected president of GCR. Dr. Brunetti is a special consultant to the assistant secretary of defense.

Ralph P. Johnson, former vice-president and general manager of Ramo-Wooldridge, has been elevated to vice-president, Electronics Divs., Thompson Ramo Wooldridge Inc.

Robert V. Meghreblian has been appointed chief, Physical Sciences Div., at CalTech's Jet Propulsion Laboratory. Within the division, **Hadley Ford** has been named chief of the chemistry section, and **John Laufer,** chief, gas dynamics section.

Samson A. Marshall has been named senior physicist at Armour Research Foundation.

Stanford Research Institute has appointed **Robert L. Tanner** manager of its Electromagnetics Laboratory.

The Martin Co. has elected **William L. Whitson** a vice-president, and has named **Maj. Gen. Eugene P. Mussett** (AF-Ret.), site integration manager of the Titan ICBM base at Ellsworth AFB, S. Dak., for the company. **Warren P. Opitz** will be manager of field installations for Martin at Ellsworth.

Gustave A. Bleyle Jr. has been named vice-president in charge of engineering at the Santa Monica, Calif., office of Arthur D. Little, Inc.

Aerojet-General has appointed **B. F. Coffman Jr.,** manager, hybrid rocket engine projects; and **Allen S. Ginsburgh,** manager, Materials and Fabrication Div. for the Solid Rocket Plant. **Richard W. Powell,** manager of the Avionics Div., has been elected chairman of the Aerospace Industries Assn.'s Electronics Equipment Technical Committee.

Barnet R. Adelman, vice-president and general manager, United Technology Corp., has been upped to executive vice-president. He will continue to serve as director of the Operations Div. **Murray A. Schwartz** joins UTC as head of its high-temperature materials program in the Research Div.

James H. Vaughan has been named director of defense products for ACF Industries' American Car and Foundry division.

Frank S. Kipp has been appointed general operations manager of special military vehicles operations, a newly established component of Ford Motor Co.'s Defense Products Group. At the Aeronutronic Div., **Ernst H. Krause** will head electronic systems operations, formerly range systems operations; and **S. Dean Wanlass** has been named general operations manager, computer products operations. **Claude A. Brosterhous** has joined the division as assistant manager, systems test and prototype fabrication for tactical weapon systems operations.

James G. Wenzel has been appointed coordinator of antisubmarine warfare programs for General Dynamics Corp. **Howard A. Bond** has been made manager of reconnaissance systems in the company's Stromberg-Carlson's Electronics Div.; **Beryl L. McArdle** has been named a scientific adviser in the S-C Div.; and **Paul S. Dove** has joined the Washington staff of the division.

Allen C. Munster has been appointed director of research operations at Philco Corp.'s Research Div. **H. French Harris** becomes manager of the Discoverer and Samos satellite projects at the company's Western Development Laboratories.

Thomas LeSueur Hardy has been appointed senior systems engineer to head Arnoux Corp.'s new Huntsville, Ala., office.

D. M. Allison has been appointed technical assistant to R. D. O'Neal, vice-president, engineering and research, Bendix Corp., and **Karl F. Kellerman,** assistant to A. P. Fontaine, executive vice-president.

Horace G. Irwin has been appointed space systems project engineer for Douglas Aircraft's Delta and Thor-Able Space Vehicle Programs, succeeding **Ted J. Gordon,** new project engineer, Saturn S-IV second stage. New

Brunetti

Johnson

Whitson

Bleyle

Adelman

Vaughan

chief engineer for Thor systems is **R. S. Saye,** who succeeds **H. M. Thomas,** now Saturn program manager for Douglas. Other appointments in the Thor project are **D. E. Brimley,** assistant chief project engineer; **N. J. Heckman,** project engineer, field station testing; and **W. H. Hess,** project engineer, missile, ground support equipment, and contract requirements.

Ju Chin Chu, professor of chemical engineering, Polytechnic Institute of Brooklyn, has been named consulting propulsion specialist to Rocketdyne.

H. Igor Ansoff has been appointed vice-president for plans and programs at Lockheed Electronics Co., a subsidiary of Lockheed Aircraft. **Edward M. Pritchard** has been named director of engineering for the Military Systems-Stavid Div. of LEC.

Ludwig Roth, former assistant director of ABMA, has joined Northrop Corp. as director of research, Norair Div. **James R. Bruce** becomes assistant manager of Northrop's Huntsville, Ala., district office. **Max Pape** has been made director of publications for the parent company.

Oleg C. Enikeieff has been appointed director of Marquardt's new Special Projects Laboratory in Washington, D.C. **O. A. Linse** becomes assistant to the vice-president of the Pomona Div.

Gerhard L. Hollander has been named manager of Hughes Aircraft's new general-purpose computer department, ground systems group.

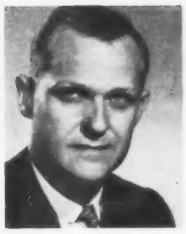
Edwin F. Shelley, president of USI Robodyne, has been appointed a group officer and vice-president of U.S. Industries, Inc., the parent company. **Hugh C. Bream** has been named president and general manager, Western Design division of USI.

James H. Fisher has been named a vice-president of Electro-Optical Systems, Inc., and will be responsible for advance planning activity. **Robert E. Wall Jr.** and **Ronald Toms** have joined the company as senior scientists in the Energy Research and Fluid Physics divisions, respectively.

Herman A. Bruson has been named vice-president, research, Chemical Div., of Olin Mathieson Chemical Corp. In the division **J. V. Karabinos** has been made director, organic research dept., and **D. W. Kaiser,** manager, special chemicals section, in the department. **A. E. Ardis** becomes director, polymers research dept; **B. H. Wojcik,** director, and **A. Pace Jr.,** assistant director, inorganic research dept; **M. C. Metziger,** director, and **C. S. King,** associate director, inorganic research dept., Joliet, Ill.

Pritchard

Fisher



Bain

Bushong

Recently joining Wyandotte Chemicals Corp. are **Bruce Swinehart,** Analytical Dept.; **Ronald Wardle,** Inorganic Dept.; **Ian Sommerville, Frank Macri,** and **Harvey Yates,** chemical engineering group.

John A. Mauro has been appointed consulting optics engineer by the Ordnance Dept. of GE.

Victor H. Harris has been named manager, New Projects Office, Vitro Laboratories.

William A. Bain has been elected vice-president of Air Products Inc. Dr. Bain is also general manager of the Defense and Space Div.

R. Merrill Bushong has been named director of advanced materials project at National Carbon Co., Div. of Union Carbide Corp. **Dario Domizi** will be manager of applications technology, AMP, and **Robert C. Stroup,** development manager of the Advanced Materials Laboratory to be built at Lawrenceburg, Tenn. **Walter P. Eatherly** will coordinate all research activities for AMP, while remaining as assistant director of National Carbon's Research Laboratories.

Joseph J. Bokan has been elected president of ITT's Components Div. at International Electric Corp., a subsidiary. **J. O. Paivinen, W. B. Deane,** and **John J. Karavish** have been named directors of engineering, systems research, and subcontracting, respectively.

Thomas A. Carter Jr. has been named manager, Cryogenics Div., Standard Steel Corp.

Robert F. Tuve has been appointed manager of quality control, Boston Div., Minneapolis-Honeywell Regulator Co., and **Charles S. Marshall,** manufacturing superintendent, Rubicon Div.

Joseph W. Selden has been upped to divisional vice-president, Chemical Div., Minnesota Mining and Mfg. Co.

G. A. Raymond has been named to manage the new Reliability Engineering Dept. at Remington Rand Univac, Div. of Sperry Rand Corp.

Raytheon has elected the following as vice-presidents: **Glenn R. Lord,** general manager, Equipment Div.; **Fritz A. Gross,** assistant general manager, Equipment Div.; and **Thomas L. Phillips,** assistant general manager, Missile Systems Div.

Alfred F. Kaspaul has been promoted to manager, Solid State Physics Dept., CBS Laboratories.

Curtis M. Lee has joined Wyle Mfg. Corp. as chief engineer, and **Arthur N. Purdy** joins Wyle-Parameters Field Engineering Dept.

HONORS

Richard Winer, assistant manager of Hercules Powder Co.-operated Allegany Ballistics Laboratory, has been awarded the 1959 outstanding achievement award of the ARS Maryland Section for his work in developing the X248 Altair rocket motor.

Theodore von Karman, chairman, NATO Advisory Group for Aeronautical Research and Development, has received an honorary Doctor of Science degree from New York Univ.

Ali B. Cambel, an ARS director and professor and chairman of the Mechanical Engineering Dept. at Northwestern Univ., has been awarded the 1960 Curtis W. McGraw award plus $1000 in recognition of his "outstanding early achievements" in research at the annual meeting of the American Society for Engineering Education.

DEATHS

Garviil Adrianovich Tikhov, academician of the Academy of Sciences, Kazakh SSR and corresponding member of the Academy of Sciences, U.S.S.R., died at the age of 85 on January 25th. Academician Tikhov devoted the major portion of his life to the investigation of the planets, particularly Mars. He is credited by the Russians with founding the field of science called astrobotany. ♦♦

Careers in astronautics

By **Irving Michelson**, *Pennsylvania State University*

THE CONCERN noted in this column last month over "the vanishing engineer" was traced to a cause which, we are now reminded, seems also to endanger astronautical progress in an even more direct way. The same spotlight on "science" (with the all-too seldom understood connotation that also includes engineering), which apparently diverts too many potential engineers into the sciences, may also beguile the space engineer himself into confusing scientific goals with that which the engineer brands as "feasible" when he sees a task he believes he can do soon. At least this may be inferred when one of our foremost vehicle designers finds it necessary to admonish us not to forsake entirely some less glamorous but essentially proved and workable concepts in favor of the more exotic and "scientific" schemes that nowadays command such a large part of our attention.

The particular issue, which we think deserves much thought and which we therefore review briefly below, points to some R&D areas of very great interest. We note in passing that these may be categorized as belonging to the engineering sciences predominantly, the term being used to refer to areas that somehow do not seem to belong to science purely, nor to engineering, but very much to both at the same time.

° ° °

The question is that of nuclear rockets, and the authoritative view, that of M. W. Hunter, space systems assistant chief engineer at Douglas, who feels we would be gravely remiss to overlook this relatively simple system for deep-space missions while concentrating on ionic propulsion and other fascinating but unexplored MHD concepts which may very well turn out to be much less useful than we are hoping. Mr. Hunter, who also serves ARS as its Missiles and Space Vehicles Committee chairman, recently surveyed the engineering potentialities as well as the problems associated with a nuclear rocket vehicle, concluding that manned lunar and Mars expeditions might realistically be expected within the present decade with such a system —and at operational costs that bear comparison with present-day transport scales, too.

He argues that we must not reject rocket-engine performance which is a mere 100 per cent superior to chemical rockets, for that is roughly what a nuclear rocket using hydrogen as working fluid would deliver. Even allowing that high reactor cost would dictate use of recoverable engines, some fairly startling conclusions are drawn. For example, a nuclear rocket-propelled lunar vehicle with half the payload of a DC-8 would have a gross weight only one-twentieth that of a similar rocket with chemical propulsion, taking the latter for comparison because it alone of all competitive systems might be ready to fly in the '60's. Required energy expenditure for the single-stage, recoverable vehicle is estimated as of the same order as that of present-day air transports on typical cross-country flights. Only moderately greater energies would reduce flight times sufficiently to permit serious consideration of regular operation to Mars and Pluto, moreover.

If these claims strain our credibility, it helps to recall that the humble factor of two, by which the nuclear rocket improves performance over chemical systems, enters into the pertinent relationship for total flight performance through exponential powers, and hence has immensely stronger influence than the number itself suggests.

° ° °

It is easy to see how much importance will attach to studies aimed at the development of high-temperature materials, if a major effort should be ordered for nuclear rocket vehicles, because the factor of two mentioned above is limited chiefly by thermal restrictions in the rocket reactor. It is comforting to recall rumors of the past year about the government's strong interest in establishing a major and very high-level center for the exclusive purpose of furthering our materials capability broadly. Nuclear rocket development would, of course, be a major beneficiary of such progress.

° ° °

Problems of radiation shielding are also of tremendous importance for nuclear rocket operations, not only in relation to the materials, but even more so for transport or exploration missions involving passengers. Shielding weights are ordinarily quite large, and the question of reducing this weight is posed here with a new wrinkle: Reactor operating times for deep-space missions remain a matter of several minutes only in flights of many days' duration. Can this fact justify drastic reductions of shielding thickness? Passengers also require protection from the natural radiations into which any space vehicle carries them, of course, and we hope the space-biologists are getting the data from earth satellites and cosmic explorers on which to base realistic recommendations.

If nuclear rockets should be adopted for interplanetary flights, we also face the question of whether each flight will carry all the working fluid it will need for the round trip, or whether cheaper ways can be found to provide the required hydrogen at the far terminal. Other supplies, too, must be considered, and many of these are so much more durable than the passengers that we might expect to need at least two different classes of vehicles, one of which provides for "services" alone. Cargo cost is put at $10/lb round trip to the moon, and the same figure is estimated for the one-way trip to Mars under ideal conditions from a seasonal viewpoint. Moreover, if thermal problems in reactors are solved sufficiently to double exhaust velocity, the costs mentioned would be reduced by an entire order of magnitude—a strong incentive indeed.

° ° °

Returning to the question of our vanishing engineers, we see that declining engineering enrollments have been the subject of some study by the Engineering Manpower and Scientific Manpower Commissions. Surveys they have recently conducted show that the sciences have not only gained in enrollment to balance losses in engineering, but also absorbed the major portion of a significant total growth of enrollment in our colleges and universities within the past five years. A question they then pose is to what degree the increasing emphasis on science within the engineering curriculums is promoting the trend. ♦♦

Project Mercury Report

(CONTINUED FROM PAGE 33)

a periscope, which is centered below the instrument panel, and the window directly above the panel. The Astronaut will be able to see the horizon in back of the capsule through this window in the normal orbital attitude of 14 deg, as well as in the retrofiring attitude of 34 deg. The periscope provides the Astronaut with a view of the earth beneath the capsule. He can control the attitude by location of the earth's image in the periscope.

The instrument in the left center is a dead-reckoning device based on a small model of the earth, clock-driven to rotate in time with the orbit. In the right center is the main capsule clock, which, in addition to firing the retrorockets, indicates time of day, the lapsed time since launch, and time-to-go for retrorocket firing. The Astronaut also has an additional time-to-go dial, which he can set for any desired event, and a separate stop watch.

The instruments grouped in the upper right-hand corner of the panel follow the environmental-control system: Cabin pressure, temperature, relative humidity, and oxygen partial pressure; primary-and emergency-oxygen-supply pressure; and carbon-dioxide partial pressure downstream of the lithium hydroxide canister in the pressure-suit control system. This portion of the panel also has controls for the cabin-pressure-system fans.

A light panel, adjacent to the environmental-control-system instruments, gives the Astronaut visual warning of major system failures. At the same time, an alarm sounds when a failure occurs. The Astronaut turns off the auditory warning signal by actuating a switch located by an associated light and then takes corrective action. Warning lights are provided for loss in cabin pressurization, depletion of primary oxygen supply, emergency-rate mode of operation, decrease in cabin oxygen partial pressure below 3 psi, increase of carbon-dioxide partial pressure to 3 per cent in the pressure-suit circuit, and excessive cooling water to the suit and cabin heat exchangers.

Manual Backup Controls

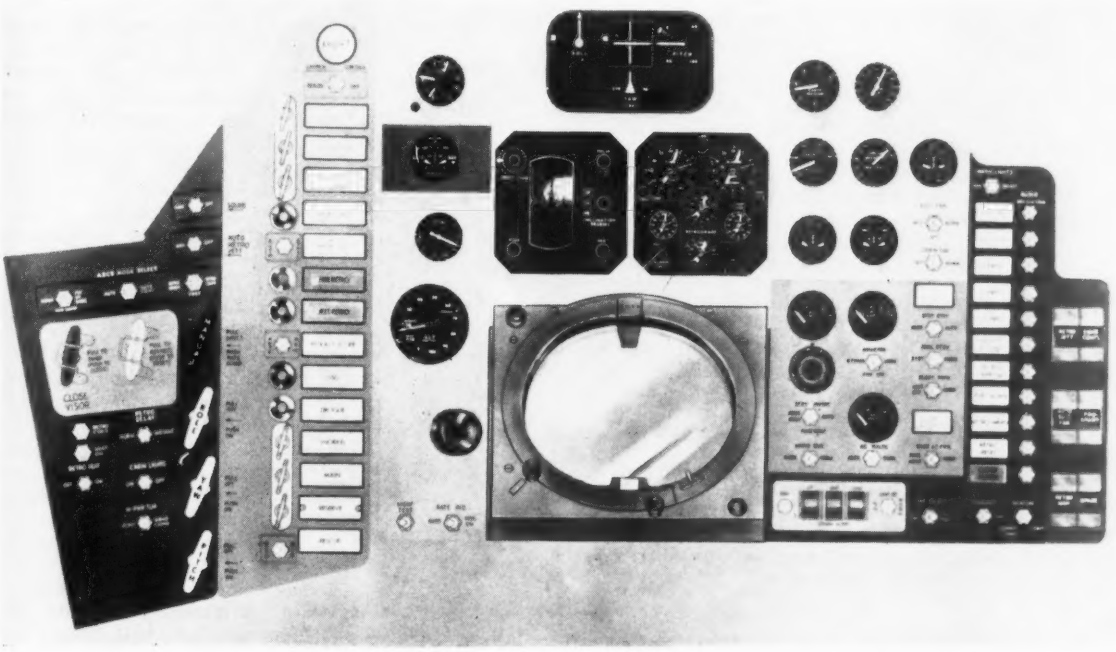
A telelight panel on the left console gives the Astronaut indication of light-event sequential operation. The launching oxygen supply and snorkel operation are also shown on this panel. Manual backup controls are installed adjacent to the lights. Heat-exchanger water-flow controls and the emergency-rate valve control are located on the right console, which is not shown in the illustration below.

The instrument panel and Astronaut will be photographed in flight. In addition, instrument data will be telemetered and will be recorded on board. The Astronaut's electrocardiogram, body temperature, and respiration rate and depth will also be taken and recorded on board and telemetered continuously.

The environmental-control system, diagrammed on page 74, maintains the environment for the Astronaut at a temperature between 50 and 90 F. The Astronaut can manually select the temperature in this range that makes him most comfortable. During reentry, when the cabin air temperature may approach 80 F, his suit will still maintain its air within the desired temperature range. The system is capable of operating for about 32 hr. Body odor is removed by activated charcoal, and carbon dioxide is removed by lithium hydroxide. Fresh oxygen enters the suit at the torso and exits at the helmet. As oxygen leaves the helmet, it enters a debris trap, where small particles are removed, and then goes through the odor and carbon-dioxide absorbers. A filter downstream of the carbon dioxide absorber prevents lithium-hydroxide dust from contaminating the oxygen. Pressure drop is counteracted by an increased supply of gas from the oxygen bottle. Ten cubic feet per minute is the flow rate through the suit at approximately 5 psi. Considering the fact that this system only weighs about 130 lb, it represents indeed a noteworthy engineering accomplishment.

Among the more complex systems in the capsule is the one for automatic stabilization and control. The illustra-

Astronaut's Instrument Panel



tion below shows the normal operation of this system. When the Atlas booster engines drop, an event known as staging, the capsule ejects the escape rig by firing a special jettison rocket. The Atlas booster then follows a tilt program which yields an orbital altitude of approximately 105 n.mi. at the time of insertion. At booster cutoff, the capsule's "posigrade" rockets fire, separating the capsule from the booster. The stabilization system maintains capsule rate damping for 5 sec, until all oscillations of the capsule have been stopped. The capsule orients to the retrorocket firing attitude for 5 min. Within this period, ground tracking stations will determine if the velocity and insertion angle attained will allow the capsule to maintain itself in orbit.

Emergencies Anticipated

The capsule then orients into the normal orbital attitude — $14^1/_2$-deg, blunt-end-up position. This permits the Astronaut, with the aid of the periscope, to see past the heat-shield end. Also, the retrorockets point in the right position for re-entering immediately, in case of emergency.

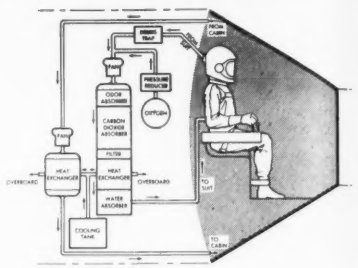
The automatic stabilization and control system next orients the capsule into the retrofiring attitude. After retrofiring, the capsule orients to the reentry attitude, and the retropackage is jettisoned. As the capsule enters the atmosphere, the control system introduces a roll rate of 10 to 12 deg/sec and maintains rate damping, which prevents large capsule oscillations from building up. At about 42,000-ft altitude, the drogue parachute deploys, stabilizing the capsule prior to deploying the main parachute at 10,000 ft. At water impact, there is released a small balloon carrying an antenna aloft to aid in capsule recovery.

One of the major concerns has been to protect the pilot from excessive accelerations during flight and landing. The escape rocket, if fired in an off-the-pad abort or at high altitude where the drag forces are low, would place upon the Astronaut an acceleration level of 20 g for a period of almost 1 sec. Impact on the water would give accelerations as high as 40 g for a few milliseconds.

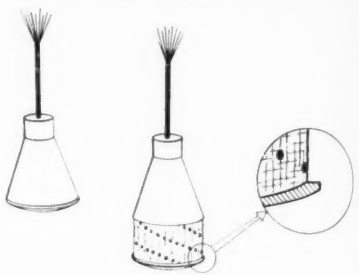
The contoured couch developed for the Astronaut evenly distributes his weight. Normal exit g-profiles run with the couch demonstrated its efficacy in helping the Astronaut do tasks which are necessary for normal capsule functions. Tests in which accelerations reached values as high as 25 g also demonstrated the validity of this support system in the case of escape-rocket firing.

A major problem still existed, however, in land impact or impact on the water with a high horizontal-wind profile. It is believed that a satisfactory solution to this problem has been accomplished by the accordion-like air cushion shown at right. The air cushion consists of a 4-ft skirt made of rubberized Fiberglas that connects the heat shield to the rest of the capsule. After the main parachute deploys, the heat shield releases from the capsule and the bag fills with air. Upon impact, the air trap between heat shield and capsule vents through holes in the skirt, as well as through portions of the capsule not completely airtight, giving a cushioning effect.

Project Mercury Environmental-Control System



Air Cushion for Impact Attenuation

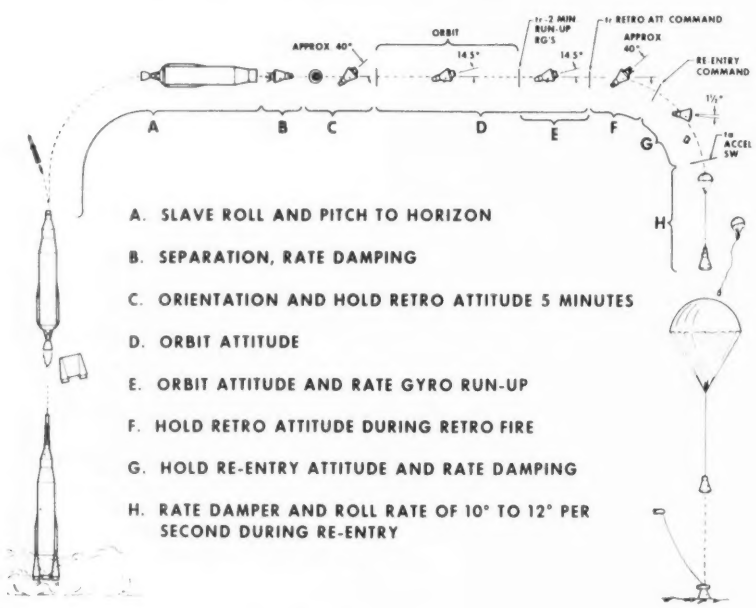


Now as to the booster for the Mercury capsule and the steps taken to assure its reliability.

The models pictured on page 75 show the three flight-test vehicles used in Project Mercury. The Little Joe is a cluster of solid-propellant rocket motors used in the research and development program. No manned flights are contemplated with this booster, although successful flights with small primates aboard the capsule have been made. The Redstone booster will be used for Astronaut training flights. Before this program begins, an animal will be flown to demonstrate the system. The Mercury capsule-Atlas combination will also carry animals before it puts a man in orbit.

The quality-control program being followed with these boosters takes advantage of all the experience gained in the weapon-system programs involving them. The reliability of each system is based upon the nominal performance of each individual component and subsystem. Also, as these systems are assembled in the various industrial plants, each part is being marked or tagged with a Project Mercury label. Although an assembly-line technique has been established for

Normal Operation of the Automatic-Stabilization Control System

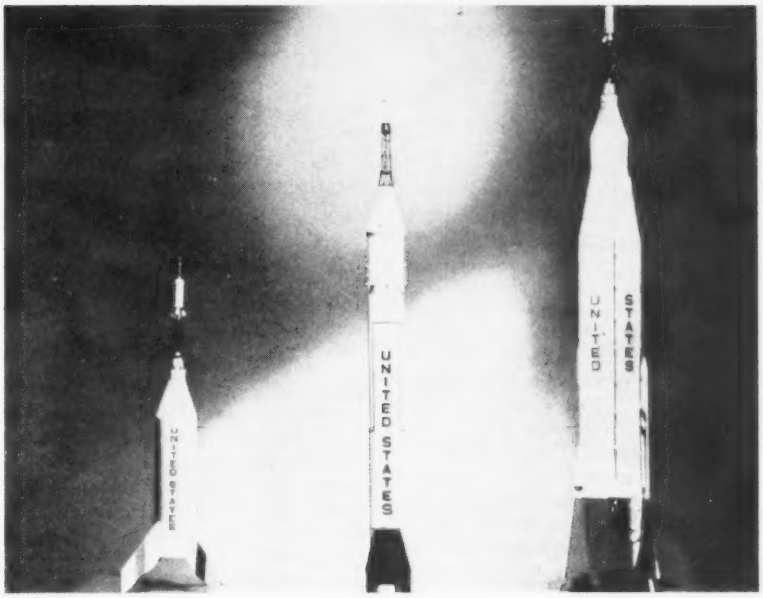


these boosters, 100-per cent inspection of all parts will take place to assure the highest possible quality control. Upon assembly of a booster system, a comprehensive rollout inspection will be made. The history of all parts going into a particular booster will be carefully documented and reviewed. In this manner, the operational proficiency of all systems and individual components should be made known.

Moreover, after a capsule has been mated with a booster and the mechanical and electrical integration completed, a flight-safety review board will be held. This review board will report on the over-all expected reliability of the capsule and booster together. Only after the capsule-booster combination meets the requirements of the flight-safety review board will approval for flight be given.

As to tracking, a total of 17 stations, including the control center at Cape Canaveral, will be active while the Mercury capsule is in orbit. Of these 17, two will be located on-board ship in the mid-Atlantic and Indian Oceans. At each tracking station there will be telemetry readout giving the personnel real-time indication of the pilot's and the capsule system's condition. Prior to each flight, aeromedical and capsule-system specialists will be sent to each of the monitoring stations; and after each flight these specialists will aid in evaluating performance. The down-range facilities of the Atlantic Missile Range will be used for the normal re-entry tracking.

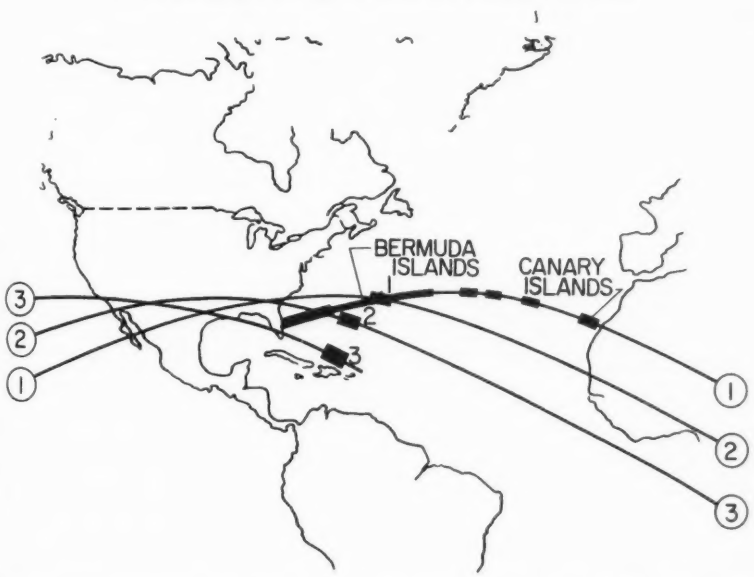
Models of Project Mercury Flight-Test Vehicles



The capsule can be followed on radar from the time it begins its re-entry until impact. Constant voice communication should also be possible during this time. The tracking facilities in the continental U.S. will be used extensively for determining the correct time of retrofiring, and thus predicting impact area. In the U.S., there are six such tracking installations.

Certain areas, shown by the chart below left, have been designated as primary recovery areas. A long recovery area, from Cape Canaveral toward the Bermuda Islands, includes all impact points in case of an early abort. Between the Bermuda Islands and the Canary Islands are other primary recovery areas. These areas are so located that if velocity or insertion angle is not correct firing of the retrorockets should cause the capsule to impact in them. If the initial orbit is not correct and conditions prevent the capsule from making three orbits, a second impact area will be aimed at toward the end of the second orbit. The impact area from a nominal flight, however, occurs at the end of the third orbit down the Atlantic Missile Range. As mentioned, this would mean continuous tracking of the capsule during re-entry from Hawaii until impact.

Main Recovery Areas Planned for Mercury Capsule



No. 1—Impact areas possible in an early abort; No. 2—Areas possible with an imperfect attempt at orbit; and No. 3—Area for a normal three-orbit flight.

Milestones

The Astronaut in Project Mercury will furnish other milestones in man's conquest of space.

The Mercury orbital missions will permit the study of the effects of prolonged weightlessness on the physiological reactions, the subjective psychological reactions, and the performance of the Astronaut. Of particular interest will be the effects of weightlessness on respiratory and circulatory systems. Telemetered electrocardio-

gram and breathing rates will make it possible to determine not only the effects of prolonged weightlessness itself, but the effects of transition from high accelerations to zero-g and back to the high accelerations associated with launch and re-entry. Problems associated with eating and drinking in prolonged weightless flight can also be studied. Stress hormone studies, together with pre- and post-physical examinations, will allow assessment of the Astronaut's physiological reaction to the spectrum of flight stresses.

Subjective psychological phenomena likely to be affected by the weightless environment can be studied through voice reports and capsule instrumentation. The ability of the Astronaut to orient himself in space can be determined. The effects of the reduction in proprioceptive cues in time estimation can be studied. And attention will be given to the extent of autokinesis and occulogyric illusions possibly arising from weightlessness and other factors.

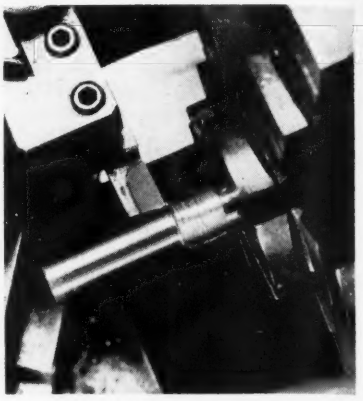
Of utmost practical importance to future manned space flights will be the quality of the Astronaut's performance in space. Accuracy in manual attitude control should provide a good test of his psychomotor performance. His monitoring of the capsule's orbital systems should provide an indication of his vigilance and perceptual accuracy. Navigation will test his reasoning and visual discrimination of earth terrain and heavenly bodies.

This is to say, we believe that Project Mercury will provide the baselines by which future space vehicles can be built around the most valuable and useful machine—man himself. ♦♦

Refractories Available As Large Single Crystals

Scientists at Linde Co.'s Speedway Research Laboratory have developed an arc-fusion process for growing refractories, such as tungsten, molybdenum, columbium, vanadium, and several compounds of these, as single crystals up to a foot long and an inch in diameter. These crystals are significantly more ductile and workable at moderate temperatures than polycrystal-line forms. Besides having a variety of boules and finished crystals available commercially off the shelf, Linde is providing a $90 sample kit of pure-metal and compound crystals for laboratory testing and analysis.

The availability of the Linde crystals should facilitate research on high-temperature materials for electronics and astronautics. George Hoffman of the Rand Corp. discusses the strength of pure crystal filaments in the Aug. 1958 *Astronautics*.



A large crystal of pure tungsten grown by Linde's arc-fusion process is shown being turned on a lathe at room temperature.

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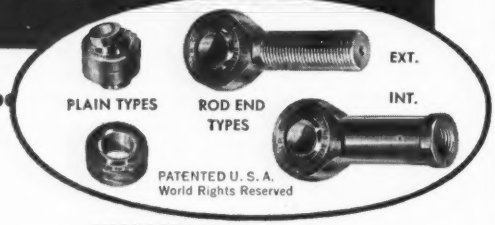

CHARACTERISTICS

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1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
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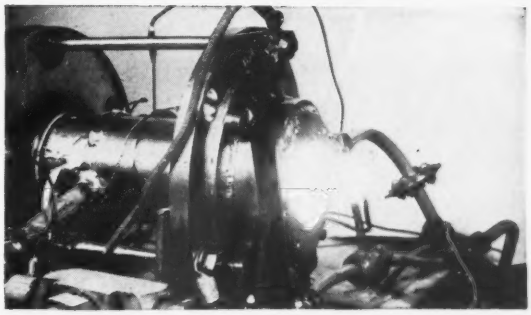

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GENERAL ELECTRIC

Cincinnati 15, Ohio

Space Flight Report

(CONTINUED FROM PAGE 29)

This new exhibit technique is being employed primarily in an effort to eliminate the confusion which usually marks large Coliseum shows, at which competing booths are frequently jammed together in such a manner as to distract and confuse attendees as they walk through the aisles.

Generous aisle space has been provided to eliminate this confusion as much as possible. In many instances, aisle space is more than 50 per cent wider than is customary for expositions of this type. In addition, there will be special exhibit listings in the meeting program broken down by category to direct attendees to the displays of greatest interest to them.

The result will be to increase the impact of the exhibits on those in attendance by replacing the usual crowded exposition conditions with open space wherever possible, thereby creating an imposing panorama of astronautical equipment.

Luncheons are planned for each day of the meeting to provide a platform for outstanding speakers in the field. These functions will be held in a specially constructed room on the third floor of the Coliseum which will hold 750 people. The annual banquet will be held in the famous grand ballroom of the Waldorf Astoria Hotel.

To handle the expected attendance of 10,000 professionals from the fields of rocketry and astronautics, more than 5000 sleeping rooms and suites have been blocked off in hotels throughout the city by the New York Convention Bureau. Arrangements for dormitory accommodations have been made for students attending the meeting.

Forms on which rooms may be reserved will be printed in each issue of *Astronautics* beginning next January.

Special hours for admission of the public to the exhibits are being arranged and a program of lectures for the layman on space flight is planned. Arrangements will also be made for guided tours of student groups. ♦♦

Re-Entry Drag Balloon

Coated-fabric balloons, similar to this 9-ft-diam one, which inflates from the drop-shell can at its base in $^1/_{10}$ sec, will be used to retard tumbling and to control the speed of instrumented nose cones, manned escape capsules, and other space payloads during re-entry, according to Chief Engineer E. A. Brittenham of Goodyear Aircraft Corp., which developed the balloon pictured for WADD. Cree shots will evaluate a combination balloon and parachute pack (Ballute) this summer.

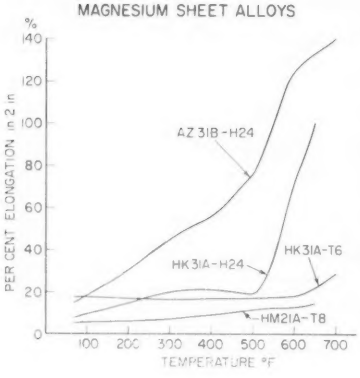
ASTRONAUTICS Data Sheet — *Materials*

Compiled by C. P. King, *Materials and Process Section, The Marquardt Corp., Van Nuys, Calif.*

MAGNESIUM SHEET ALLOYS

Magnesium sheet alloys have found wide acceptance in the aircraft and missile industry because of their excellent strength to weight, fatigue, and stiffness characteristics. The AZ31 alloy is used for its properties at room temperature, while the more recently developed thorium containing alloys, HK31 and HM21, may be used up to 800 F in short-time applications.

ELONGATION OF MAGNESIUM SHEET ALLOYS



Fabrication

Most forming of magnesium sheet must be conducted at elevated temperatures as indicated by the graph showing bend radii. Rubber forming, deep drawing, hydroforming, spinning, and stretch forming are widely used.

Joining

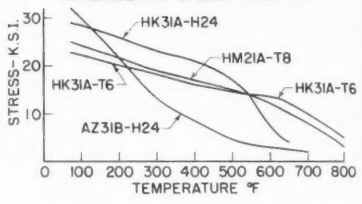
TIG and MIG welding are both employed for fusion welding magnesium. Ninety per cent joint strengths are obtainable. Magnesium sheet is also readily resistance welded. Adhesive bonding is rapidly becoming more popular as an alternative joining method.

Heat Treatment

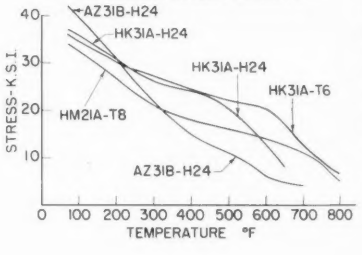
AZ31B and HK31A are usually supplied in the H24 (strain-hardened and partially annealed) condition. HM21A is supplied in the T8 (cold-rolled and aged) condition. Only HK31A responds to heat treatment. It may be solution-treated and aged to the T6 condition. This procedure improves its strength characteristics at the higher temperatures.

For maximum formability at the expense of strength properties, the magnesium sheet alloys are sometimes used in the O (annealed) condition.

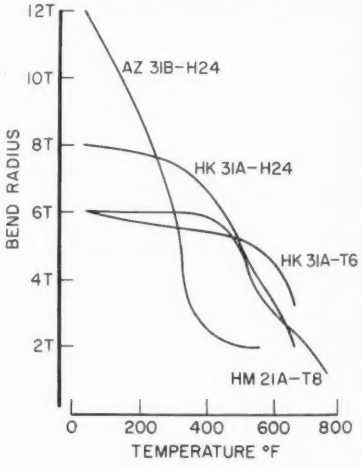
0.2% YIELD STRENGTH OF MAGNESIUM SHEET ALLOYS



ULTIMATE TENSILE STRENGTH OF MAGNESIUM SHEET ALLOYS



BEND RADIUS OF MAGNESIUM SHEET ALLOYS



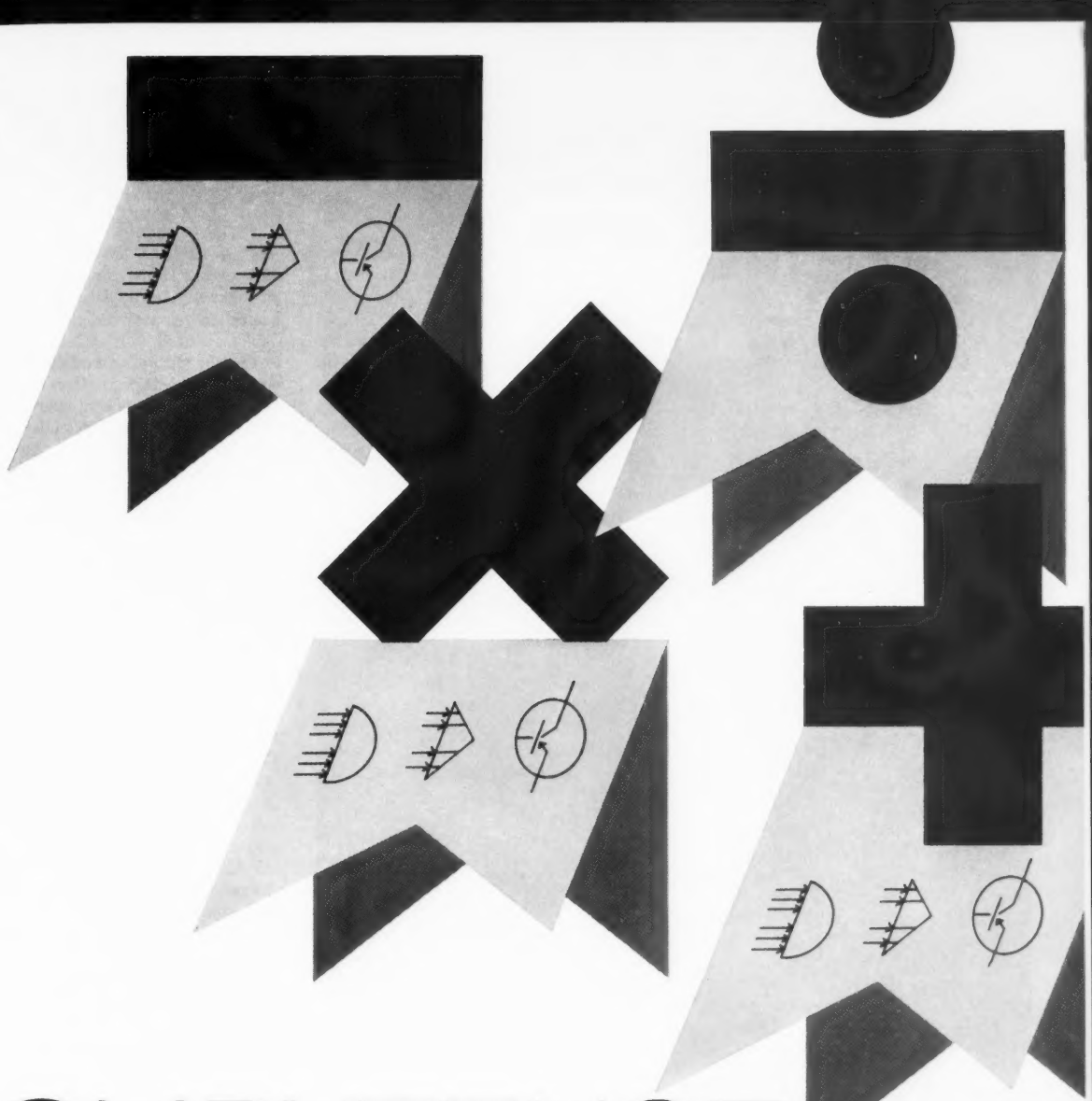
Physical Properties of Magnesium Sheet Alloys

	AZ31B	HK31A	HM21A
Coefficient Thermal Expansion, RT to 212 F; in/in/F	0.0000145	0.0000145	0.0000145
Thermal Conductivity, 68 F; CGS units	0.184	0.271	0.327
Density, lb/cu in.	0.064	0.064	0.064
Electrical Resistivity, 68 F; microhms/cu cm	9.2	6.1	5.0

Nominal Chemical Composition of Magnesium Sheet Alloys

	Al	Zn	Th	Mn	Zr
AZ31B	3.0	1.0	—	0.5	—
HK31A	—	—	3.0	—	0.7
HM21A	—	—	2.0	0.5	—

CUT ALONG THIS LINE



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CUT ALONG THIS LINE

International scene

By Andrew G. Haley

WHILE the interest of the world scientific community is now focused on the 11th International Astronautical Congress, to be held in Stockholm August 15–20, so much has been and will be written about this great gathering of scientists, engineers, jurists, sociologists, and medical experts that it seemed appropriate at this time to review briefly some of the other meetings in this field already held or to be held outside the U.S.

As far as the first of these meetings is concerned—the First Czechoslovak Conference on Rocketry and Astronautics, held in Prague in April—your correspondent has already been "scooped" by George Szego, whose excellent review of the meeting appeared in the July *Astronautics* (pp. 58–59).

However, another important event which has not as yet been covered is the "Copernicus to Lunik" exhibition organized in June by the Museum of Technical Science in Warsaw and the Polytechnical Museum in Moscow, in cooperation with the Polish Astronautical Society, the Polish-Russian Friendship Society, and the Polish Popular Science Society. W. Geisler has just forwarded complete information and photographs on this noteworthy event. The photos show some of the things which made up the exhibit—"sets" made up of large portraits of Copernicus, Newton, and Tsiolkovskii superimposed over models of the Sputniks; astronautical and astronomical devices from the earliest days of antiquity to the present time; optical and radio instrumentation; and computing instruments from the oldest times to modern electronic computers. The exhibition is scheduled to be shown in a number of European cities.

° ° °

A most impressive three-month seminar on Space Science and Technology was recently organized by the National Institute of Aeronautical Technology of Spain (INTA). The seminar got underway March 28 with lectures on current problems of astronautics and a history of rocketry by Theodore Von Karman and Frank J. Malina. Your correspondent lectured on the technical and legal regulations of space exploration on the following day.

The course, which ended July 1, covered the history and development of astronautics; astronomy orientation; physics of the atmosphere; exploration at high levels; thermodynamics; internal ballistics; engine design; nuclear, photon, and ion propulsion; plasmas; subsonic, supersonic, and hypersonic aerodynamics; heat transfer and re-entry; applications of magnetofluiddynamics; materials and structures; communications; guidance and tracking; aeromedicine and man in space; and synoptic reviews of the state of the art and future of the space sciences. Lecturers were recruited from among the outstanding scientists of many nations.

° ° °

Many records for efficiency were established by the Japanese Rocket Society on the occasion of its 2nd International Symposium on Rockets and Astronautics, held in Tokyo May 24–28. Opening remarks and addresses were delivered by M. Sanuki, chairman of the symposium committee; Kiyoo Wadati, president of the Science Council of Japan; Yasuhiro Nakasone, Minister of State and director general of the Science and Technology Agency; Takachiyo Matsuda, Minister of Education; and H. C. Van de Hulst, chairman of COSPAR. The inaugural lecture, on the course of astronautics during the next several years, was delivered by the writer.

More than 60 technical papers were presented at the meeting, and time was made available for highly interesting excursions and memorable social events. The records referred to above center on the fact that the delegates on arrival were presented with abstracts of all the papers, as well as with copies of the complete proceedings of the first Symposium (held in Tokyo in 1959)—a volume of 400 pages competently edited and sturdily bound.

° ° °

The Argentine government recently created a National Commission for Space Research (Comisión Nacional de Investigaciones Espaciales) and an Astronautics Institute for the purpose of furthering research and experimentation in the various space sciences and to promote the development of rocket technology in Argentina.

The Commission consists of a president and 18 members, representing 18 Argentinian societies and institutions. Teofilo Tabanera, honorary president of the Argentine Interplanetary Society, is president of the Commission.

A Colloquium on Space Research will be held in Buenos Aires, November 21–26, under the sponsorship of the new Commission, in cooperation with the Argentine Interplanetary Society and several other technical and scientific organizations in the country. Main topics to be covered in the Colloquium are upper-atmosphere research, rocket-propulsion systems, and space electronics, with emphasis on communications and telemetry. Present plans call for a limited number of major papers and a series of panel discussions on the above topics.

° ° °

Next month's column will center on a proposal by the Commission on Astronautics and Cybernetics of the Santos Dumont Foundation, an official agency of the Government of Brazil.

Banner Program for IAF Stockholm Meeting

The Swedish Interplanetary Society, host for the 11th International Astronautical Congress, to be held August 15–20 in Stockholm, has made known the program for the meeting. With double or triple technical sessions planned for the main meeting program, and two colloquia—on Space Law and Astrodynamics—and two symposia—on Space Medicine and Small Sounding Rockets—on the agenda, the Congress should witness the presentation of more than 200 papers reporting on work in progress or planned in most of the IAF member nations. Advance registrations indicate a record attendance of well above 500.

Most of the main program sessions, each dealing with a separate major area of astronautics, will be keynoted by a survey lecture delivered by an outstanding authority in the field under consideration. Already scheduled are lectures on the U.S. space rocket program by Wernher von Braun; on trajectories above the denser portions of the earth's atmosphere by Samuel Herrick; on the earth's atmosphere by Marcel Nicolet of Belgium; on power supplies for space vehicles by Nathan Snyder; on space medicine and astro-

biology by Hubertus Strughold; and on progress on electrical propulsion systems for space vehicles by Ernst Stuhlinger.

Extra technical sessions will be arranged to include late contributions of interest and other accepted papers not listed in the main sessions program below.

The symposia and colloquia are arousing a good deal of interest. The Space Medicine Symposium, for example, will run for two days and will include at least 15 papers. Carl Johan Clemedson of Sweden is organizing the symposium, which will include papers by Dr. Strughold, Brig. Gen. Don Flickinger (on Project Mercury), and Clark Randt of NASA (on the NASA life sciences program).

The Small Sounding Rocket Symposium, being organized by Nicolai Herlofson and Ake Hjerstrand of Sweden, will also run for two days, with about 12 papers presented. The one-day Space Law Colloquium planned by Kurt Gronfors of Sweden, is also getting considerable attention, as is the Astrodynamics Colloquium, which will be divided into three sessions, with some 20 papers presented. Organizers of this colloquium are Samuel Herrick and Erik Tengstrom of Sweden.

In connection with the Congress, a special exhibit on space instrumentation will be arranged at the Royal Institute of Technology in Stockholm where the main meeting sessions will be held. Special film showings will also be held.

Social highlights of the meeting include receptions at the Stockholm City Hall and Technical and Science Museum, a boat trip through the Stockholm Archipelago, and a visit to the famous 18th Century Drottningholm Theater. The Congress Banquet will be held Friday evening August 19 at the Grand Hotel Royal.

Papers accepted for presentation at the main program sessions are as follows:

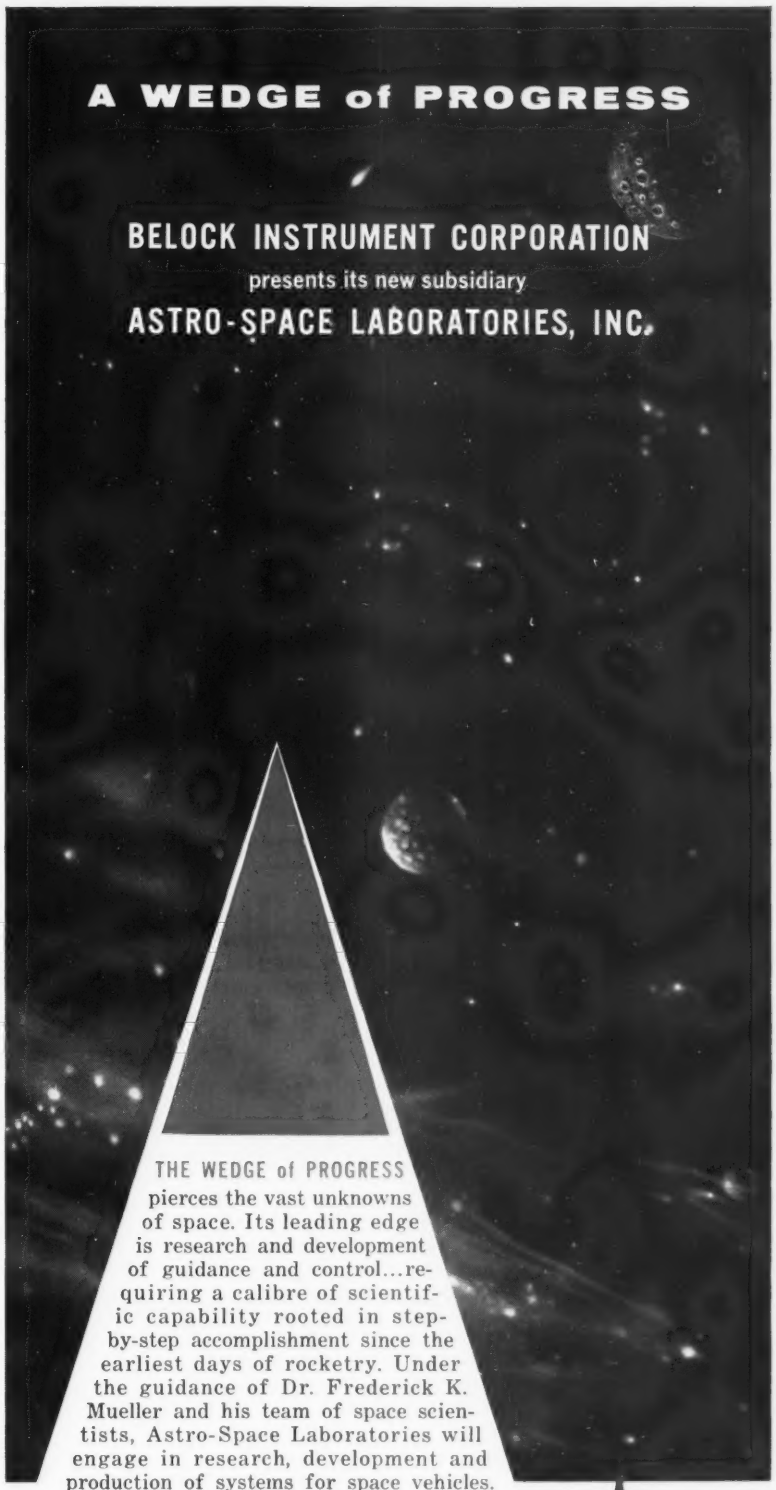
ATMOSPHERE

Chahine, M., College of Engineering, Richmond, Calif., "Free molecule flow over non-convex surfaces"; Friedman, H., U.S. Naval Research Lab, "Optical determinations of atmospheric structure"; Hermann, R., Univ. of Minnesota, "Evaporative film cooling of blunt bodies in hypersonic flow and its application to re-entry vehicles"; Manheimer-Timat, Y., Israel Ministry of Defence, Haifa, "Ionization measurements in shocked gases"; Thouvenin, J., Societé Francaise d'Astronautique, Paris, "Conductivite electrique de l'air sous l'action d'une onde de chocformation de NO"; Broglio, L. Associazione Italiana Razzi, Rome, "General solutions for re-entry trajectories with variable lift and drag and ablation."

INTERPLANETARY SPACE

Boischot, A., Observatoire Meudon, Meudon, S&O, France, "Relation entre les emissions radioelectriques et les rayons cosmiques solaires"; Kovalevsky, J., Observatoire de Paris, "Exploitations de l'etude dynamique d'un satellite artificiel"; Krassovsky, V. I., U.S.S.R., "Research of the upper atmosphere and interplanetary gas with the help of artificial satellites of the earth

(CONTINUED ON PAGE 90)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MHD Power Generation

(CONTINUED FROM PAGE 25)

brushes or slip rings—that is, metal-to-metal contact. With a gaseous conductor, however, there is the well-known problem of getting electrons to go from an electrode into the ionized gas; the electrons in a metal must be given an energy greater than the work function of the electrode before they will leave the surface.

The same problem applies to the cathode in vacuum tubes. To obtain sufficient emission, the cathode is heated with a filament to supply thermal energy to the electrons. In addition, the cathode is coated with a material such as thoria which has a relatively low work function.

For a practical MHD generator, however, the current densities must be much larger than those in a vacuum tube. The emitting surface must therefore be much hotter, probably of the order of 3000 K for graphite electrodes and somewhat lower for thoria. Thus, if the gases are at 3000 K, the electrodes can be heated to emission by contact. The problem of maintaining the integrity of the MHD channel at these temperatures is one of the central difficulties. On the other hand, if some way is found to obtain the proper gaseous electrical conductivity at lower temperature, say 2500 K, gas heating of the electrodes may not be sufficient. Practical alternates to thermionic emission thus become of considerable interest.

Hall Effect

A significant aspect of the power-generation mechanism lies in the fact that the presence of the magnetic field reduces the current flow in the direction of the electrical field.[2,4] The electrical field accelerates electrons in the opposite direction. As the electrons acquire velocity in this direction, however, the magnetic field causes them to be accelerated in the direction normal to its trajectory, and the electron paths become curved. The mean free path along the trajectory is constant; hence, the mean free path in the direction of the electrical field becomes foreshortened, and there is a net electron drift at right angles to the electric and magnetic fields. The Hall effect thus causes the electrical conductivity to be a tensor. The controlling parameter is the product of the electron cyclotron frequency, ω_e, and the electron mean collision time, τ_e. This situation is shown in the little drawings on page 84 in terms of the electric field in the gas, E^*, and the electric current vector, j.

At large values of $\omega_e\tau_e$ (outside the range of interest of MHD generators), the ion motion begins to decrease the magnitude of the electric-current vector. Practical considerations of size require that the MHD generator operate under conditions where $\omega_e\tau_e$ is between 2 and 7. For a generator with continuous electrodes, the reduction in conductivity due to the Hall effect is reflected in a serious reduction in generated power density.

One method of alleviating the problem is the use of segmented electrodes,[5] as illustrated at the top of page 85. If each pair of electrodes is connected through its own load, the

Properties of Structural Refractory Materials for MHD Applications

Material	Melting Point (C)	Density (gm/cc)	Oxidation Resistance	Thermal Shock Resistance	Thermal Conductivity (cal-cm/cm²-sec-C)	Thermal Expansion (cm/cm-C)	Electrical Resistivity (ohm-cm)	Temp of Appreciable Volatility (Max Service Temp)
Oxides								
SiO_2	1710	2.20	Excellent	Excellent	0.002 (1200 C)	5×10^6 (20–1280 C)	5×10^4 (1000 C)	1400–1500 C
Al_2O_3	2080	3.96	"	Fair	0.0173 (1800 C)	8×10^6 (20–1580C)	1×10^6 (1100 C)	1950 C
ZrO_2*	2650	5.56	"	Good	0.0058 (1400 C)	5.5×10^6 (20–1200 C)	3×10^2 (1200 C)	2300
ThO_2	3330	9.64	"	Poor	0.006 (1400 C)	9.5×10^6 (20–1400 C)	1.5×10^4 (1200 C)	2400
HfO_2	2780	9.68	"	Good	n.d.	n.d.	n.d.	2300
Mixed Oxides								
$CaZrO_3$	2320	1.54	"	?	n.d.	n.d.	n.d.	n.d.
$SrZrO_3$	2700	n.d.	"	?	n.d.	n.d.	n.d.	n.d.
$BaZrO_3$	2700	2.25	"	?	n.d.	n.d.	n.d.	n.d.
Carbides								
ZrC	3510	6.7	Poor	Good	0.049 (20 C)	6.73×10^6 (24–5000 C)	6.34×10^{-5} (Rm. Temp)	nonoxidizing[a] 2240 C oxidizing ?
TaC	3860	14.5	"	"	n.d.	8.2×10^6 (25–800 C)	2.0×10^{-5} (Rm. Temp)	nonoxidizing 3780 C oxidizing—pyropharic at room temp
HfC	3910	12.2	"	"	n.d.	n.d.	1.09×10^{-4} (Rm. Temp)	nonoxidizing 2240 C oxidizing ?
Carbon								
Graphite	3700s	1.80	"	Excellent	0.131 (1200 C)	1.0×10^6 (20–1200 C)	$1.2 - 8 \times 10^{-1}$ (Rm. Temp)	nonoxidizing 2700 C oxidizing 500 C
Pyrolytic Graphite	3700s	2.20	"	Good (delamination)	$\perp$ = 0.02 (2100 C) $\parallel$ = 0.2 (2100 C)	$\perp$ = 200 × 10 20–1200 C $\parallel$ = 0.5 × 10^6 20–1200 C	$\perp = 2 \times 10^{-1}$ $\parallel = 6.10^{-5}$ (Rm. Temp)	nonoxidizing 2800 C oxidizing 800 C
Nitrides								
BN	3000s	2.25	Good	Excellent	$\perp$ = 0.364 $\parallel$ = 0.760 1000 C	$\perp = 4.17 \times 10^6$ $\parallel = 0.43 \times 10^6$ 25–1000 C	1.2×10^4 (1000 C)	non-oxidizing 2980 C oxidizing 1100 C

*—Stabilized (cubic phase). s—Sublimes. n.d.—No data. $\perp$ = Perpendicular crystal orientation. $\parallel$ = Parallel crystal orientation.

(a) Oxidizing and Nonoxidizing refer to environment.

electric field will now be at some angle to the generator axis. Then the generator power becomes independent of the value of $\omega_e\tau_e$ for values of $\omega_e\tau_e$ of interest, and the loss due to the Hall effect is not significant. There are, however, other losses introduced.

Flow Containment

Present MHD-generator concepts imply high operating temperatures and a corrosive environment, the latter caused in part by the required seeding. Different electrical properties must be maintained at various portions of the channel walls; the channel itself may have a complicated geometry. But for stationary application, lifetimes at least of the order of months must be attained. The materials problem thus looms as the central factor in any practical consideration of MHD.

A silica wall has been used in one power-generation experiment.[13] For runs of short duration (10–30 sec) this material has held up well. Other compositions doped with refractory oxides and graphites are a possibility. The microstructure of such materials is known to have an important role in their properties; this adds to the importance of considering fabrication techniques.

Several classes of refractory materials and their properties are listed in the table on page 82. With the exception of silica, alumina, zirconia, boron nitride, and graphite, all are relatively new and exotic as far as applications go. Considerable work remains to be done on high-temperature properties and fabrication techniques.

Losses

The equivalent turbine efficiency of the MHD generator can be measured as the ratio of the power output to the flow work. The major losses[11] which occur to decrease this efficiency are as follows:

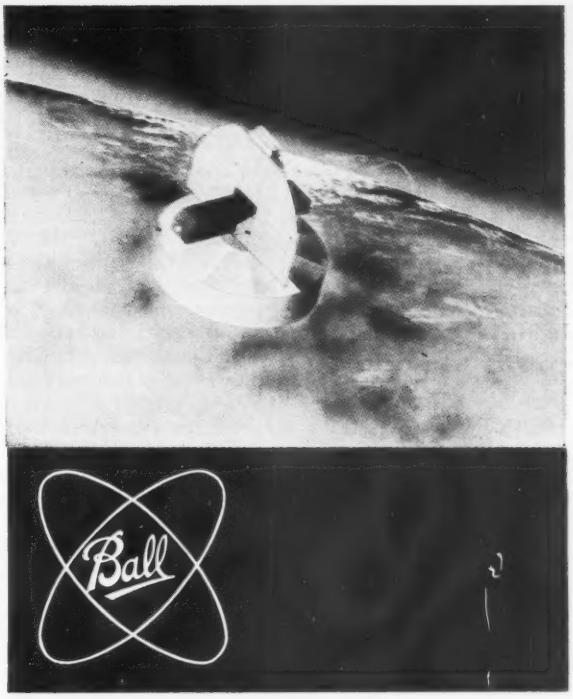
1. *Ohmic heating of the gas,* caused by its relatively low electrical conductivity.

2. *Eddy current losses* as the flow passes into and out of the magnetic field; these losses have been theoretically analyzed, and measurements are now required.

3. *Boundary layer losses;* any flow suffers viscous pressure loss; such losses have been analyzed for laminar (Hartmann-type) but not for turbulent flow.[8]

4. *Anode and cathode voltage losses;* voltage drops have been calculated by Langmuir and Tonks[20] for a stationary mixture of electrons and ions and for small currents.

5. *Hall currents* add to ohmic losses when segmented electrodes are used.



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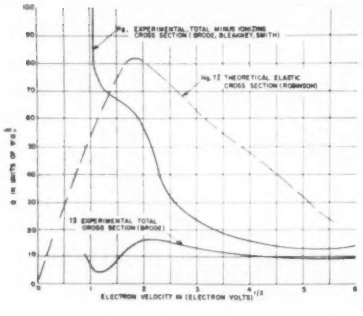
By way of comparison, ohmic heating, which is probably the most important loss, is reduced in the conventional alternator by making the internal impedance much smaller than the impedance of the load. This is relatively easily accomplished with copper and reflected in a reasonable size alternator. In the case of a gaseous conductor with a conductivity perhaps six orders of magnitude below that of copper, a comparable value of internal impedance would require a channel length of several hundred feet. A reasonable channel length results in internal losses as high as 20 per cent. This is illustrated in the graph on page 85, for a generator with constant flow velocity.

The third kind of loss associated with viscous boundary layers causes important losses in viscous dissipation, flow separation, and three-dimensional effects in a turbine. In the MHD generator, the Reynolds number will be much larger, since the reference dimension and flow velocity are larger. Hence, in comparison, these losses will be smaller. The presence of a magnetic field will also reduce the friction coefficient by thickening the boundary layer. The nonuniform velocity profile does not cause electrical losses; it can be readily shown that the power generated depends only upon the mean velocity and mean conductivity averaged over a cross section of the channel.

Finally, there are the end losses,[10] which are the counterpart of eddy-current losses in conventional generation. These losses arise because the ionized gases upstream and downstream of the magnetic field act as a shunt on the generator. The graph on page 85 shows this effect as a function of the generator loading for a channel with an aspect ratio of 6. Extending the magnetic field tends to reduce these losses. Another method is to insert insulating vanes—e.g., refractory or transpiration-cooled metal vanes—in the channel upstream and downstream of the magnetic field.

Electron-Scattering Cross Sections for Mercury and Thalium


Hg, EXPERIMENTAL, TOTAL MINUS IONIZING CROSS SECTION (BRODE, BLEAKNEY, SMITH)
Hg, T2 THEORETICAL ELASTIC CROSS SECTION (ROBINSON)
Tl EXPERIMENTAL TOTAL CROSS SECTION (BRODE)
ELECTRON VELOCITY IN (ELECTRON VOLTS)^1/2

Cold gas jets would be satisfactory in this application; the low conductivity associated with the low-temperature injected gas could increase the shunt resistance and reduce this loss.

Power Generation Experiments

As may be seen, the two central problems in MHD are associated with the electrical conductivity and the behavior of materials at temperatures of the order of 3000 K. The recent interest in MHD has in no small measure been stimulated by the development of sources of high-temperature plasmas. Some properties of state of gases have been investigated in shock tunnels[9] and electric arcs. Materials studies and actual power-generation experiments requiring longer testing times and high gas velocities have been made in electric-arc-heated wind tunnels, which have been developed over the past few years in connection with the ablation solution of the reentry problem.

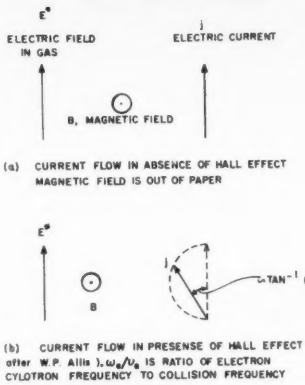
The table on page 25 lists pertinent characteristics of other experimental facilities in which some aspects of power generation can be observed. The testing regime of interest probably lies between pressures of 0.4 to 4 atm, temperatures between 2500 and 3500 K, and flow velocities in the range of 500 to 2000 meters/sec. The gaseous conductor should have well-defined properties and the experiment should be of reasonable size and duration. A review of this table indicates that no single facility at the present can be said to be outstanding.

The table on page 25 gives results of actual "power" generation experiments. It would appear that feasibility has been demonstrated by these experiments. Certainly, the experimental results cannot be ascribed to stray fields, both from the point of view of magnitude and dependence on seeding and magnetic field strength. It would appear, also, that the required conductivities can be achieved by a combustion process. Whether materials can be developed to operate at 3000 K with the requisite electrical properties and for lengths of time suitable for stationary applications remains to be demonstrated.

MHD Generator Design

A simple approach to the design of an MHD generator is to follow the configuration of an induction pump and attempt to use a straight duct of constant cross section.[16] In such a generator, if the flow is initially subsonic the temperature decreases, and as the flow approaches the appropriate Mach number the flow chokes. If, on the other hand, the flow is initially supersonic, the Mach number decreases, and a shock wave may result.[8]

Hall Effect in Gases


E*
ELECTRIC FIELD IN GAS
j
ELECTRIC CURRENT
B, MAGNETIC FIELD
(a) CURRENT FLOW IN ABSENCE OF HALL EFFECT MAGNETIC FIELD IS OUT OF PAPER
E*
B
j
TAN^-1 (ωe/νe)
(b) CURRENT FLOW IN PRESENSE OF HALL EFFECT (after W.P. Allis), ωe/νe IS RATIO OF ELECTRON CYLOTRON FREQUENCY TO COLLISION FREQUENCY

Some guidance on proper design of an MHD generator can be obtained from examination of axial turbine designs, which reveal that the cross-sectional area invariably increases in the downstream direction. Since the essential aspects of the flow theory are similar, it seems reasonable to investigate similar geometries for the MHD generator.

The method of loading of the generator must also be considered. Over a short length, the equivalent turbine efficiency is very nearly equal to the ratio of terminal voltage to induced voltage, called the loading factor, K. It seems desirable to design the generator so that the conversion efficiency is constant along its length; thus, the loading factor must be kept constant. For such a constraint, a theory has been developed to determine a suitable geometry.[14] The graph on page 85 shows some results for segmented electrodes and constant velocity flow, which corresponds to a reaction generator; constant-temperature flow, which corresponds to an impulse generator; and some other less-interesting flows. The reaction generator has the shortest length. The conductivity was assumed to be constant, and the loading factor was 0.5. Actually, larger loading factors may be more desirable to reduce the ratio of inlet to outlet pressures, even though the generator length would be increased.

From this last graph it can also be seen that an increase in the inlet Mach number reduces the length. At present, supersonic velocities do not appear practical because of the large reduction of electrical conductivity, corresponding to the lower static temperatures, associated with higher Mach numbers.

The design of a suitable magnet presents some major problems. While in a conventional alternator the magnet gap can be made arbitrarily small, in

the MHD generator all of the working fluid must pass through the gap—a measure in feet for a stationary application. Since the power used by the electromagnet is proportional to the gap, this is a major loss (up to 10 per cent) for a stationary plant. On the other hand, for units of 1 to 10 kw, the generator cross-sectional area is small, and gaps of the order of an inch may be satisfactory.

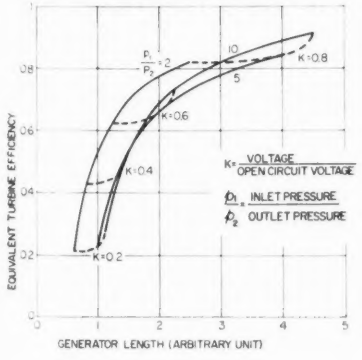
Although the injection of an easily ionizable "seed" material is not a problem, the economics of stationary power require that this material be recovered. This can be accomplished easily for a closed cycle. For an open cycle, separation from the flue gases and recovery is a major problem. Condensation of the seed material in the flowing gas can also result in excessive erosion in other parts of the system.

Applications

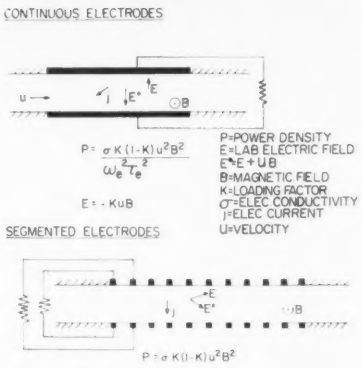
The apparent success of the "power"-generation experiments has encouraged detailed application studies.[12] For central station power in which coal is burned with preheated air to about 3000 K, an improvement in over-all efficiency of perhaps 10–15 per cent may be attainable (see diagram on page 23).

It is not at all apparent at this time, however, that materials can be developed to withstand the high converter temperatures for periods acceptable for central station use. In any case, a lengthy program of materials development will probably be required. In addition, the MHD generator, when feasible, will have to be measured against more conventional improvements of steam cycles apparently well underway—such as diphenyl cycles, gas-turbine topping units, and vapor metal cycles. Thus, while there is a great deal of promise, ignorance of the hard facts of reliability and comparative cost make a complete evaluation premature.

Generator Efficiency and Length for Various Pressure Ratios and Generator Coefficients



Comparison of Segmented and Continuous Electrodes, $\omega_e\tau_e$ Not Negligible



A somewhat different picture exists for airborne applications, particularly ones with short duty cycles. For small specialized units of capacity of 1 kw to perhaps 100 kw, it is possible to limit the field winding losses to less than 30 per cent of the power output. In addition, small units have small cross-sectional areas. For example, a 1-kw unit will have a cross-sectional area of only a fraction of a square inch. Thus, it is possible to consider the use of permanent magnets which do not consume power. A preliminary study of small units indicates that they may become competitive, on a weight basis, with airborne gas turbogenerators.

For continuous airborne or spaceborne power, the source of energy cannot be chemical. It must be either solar or nuclear because of the weight of conventional fuel that would be involved. Small solar reflectors can be built which will give a boiler temperature of approximately 2800 K; this is suitable for a 1-kw unit. For larger units, the problem of erecting an accurate solar reflector becomes appreciable, and it is not likely that units much over 10 kw operating on a solar source can be built. Gas-cooled nuclear reactors look theoretically attractive. The fact that they would have to operate at temperatures more than twice as high as have been achieved in continuous operation to date would indicate a need for considerable additional development.

Conclusions

Appropriately high gas conductivities and reliable flow containment at temperatures above 2500 K appear as the central initial problems of MHD power generation. It thus seems that the future depends on favorable answers to the following critical questions:

1. Can the gas conductivity be enhanced from values of the order of 20 mhos/meter (available at 2400 K, 1 per cent potassium, and 1 atm) to 100 mhos/meter at less than 2500 K?

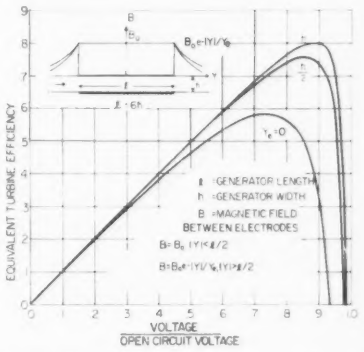
2. Can materials and structures be developed which operate at temperatures of the order of 2500 K in reactive atmospheres for extended periods of time for stationary power application, manufactured in complicated geometries, either directly or with the aid of gaseous or magnetic containment?

3. Are there practical alternates to thermionic emission for cathode use?

4. Is direct AC conversion feasible? This plaintive question is pertinent for almost all exotic power-generation schemes.

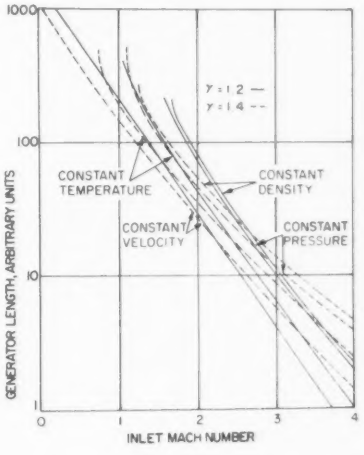
It would seem that a considerable gain in basic understanding of high-temperature technology will have to be attained before definite answers can be given. Since scale effects are probably not significant, this can be

Generator Efficiency



Considering End Losses for Channel Length Equal to Six-Times Channel Width

Generator Length Required for Different Constraints for a Reduction of Total Enthalpy of 10 Per Cent



sought in relatively small experimental facilities. A satisfactory answer will almost surely require some inventions.

The question, therefore, whether MHD allows a *practical* advance in the generation of electric power, while fascinating, cannot be answered at the present.

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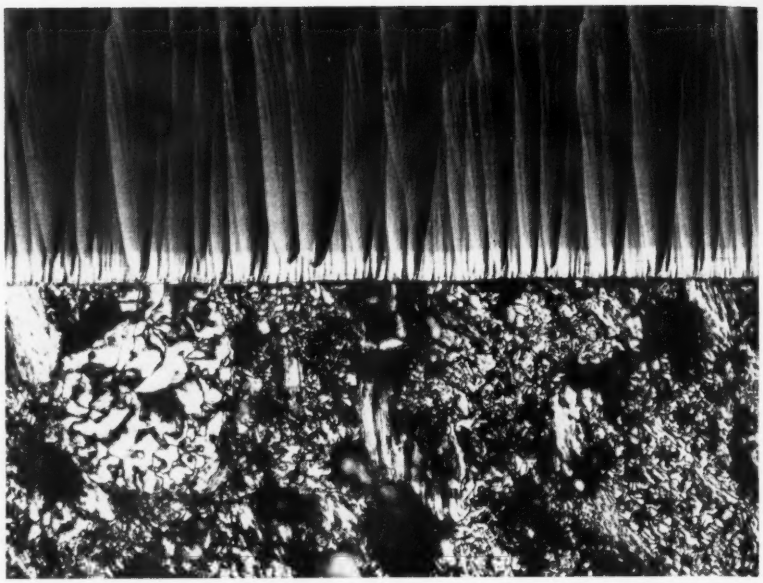
Apache Flight-Tested

Thiokol's low-cost Apache rocket motor has been flight-tested successfully at White Sands, carrying a 35-lb payload prepared by New Mexico State Univ. to an altitude of nearly 40 miles. The motor for the 223-lb system measures 104 in. long and 6.75 in. in diam, and sells for less than $1500 in quantities, according to Thiokol, which has produced Apache to aid modest school and industry rocket research programs.



Pyrolytic Graphite

The microphotogram shows ordinary graphite below and pyrolytic graphite formed above. GE Research Laboratory has produced a rectangular piece of pyrolite $^1/_8$ x 17 x 31 in.—perhaps the largest to date—and is working vigorously on a commercial process for this material of astounding strength-to-weight ratio at high temperature. Commercially available pyrolytic graphite manufacturable in various forms would find important applications in nose cones, jet vanes, nozzles, nuclear reactors, and other missile and space-vehicle systems.

Computing the Future

Wernher Von Braun, right, director of NASA's new Marshall Space Flight Center in Huntsville, Ala., discusses the use of the Center's recently acquired IBM 7090 computer for the Saturn Project with Helmut Hoelzer, left, director of the Computation Div., and Eberhard Rees, deputy director for research and development. The first of its type to be installed by IBM for scientific or commercial data processing, the 7090 can add over 13 million numbers per minute. Marshall was slated to receive a second 7090 last month, and modified versions of the 7090 are being incorporated into BMEWS.

SPLIT—SECOND INFORMATION

An effective Army must have split-second, exact combat intelligence. Republic's Missile Systems Division is working on one means of fulfilling this need for the U. S. Army with the AN/USD-4 Swallow system: a completely integrated ground-airborne information-gathering system.

The SD-4 system includes an all-weather, jet-powered surveillance drone, mobile ground command and information stations, and associated ground support equipment. The drone will be field-launched and employs any of a number of surveillance sensors. This high-performance unit will permit the field army commander to extend his view beyond the horizon to gain up-to-the-minute information. Its mission completed, the SD-4 will return, be recovered and readied for a new mission.

The airborne-ground SD-4 Swallow system was designed and is being developed by Republic's Missile Systems Division under contract to the U. S. Army Signal Corps.

REPUBLIC AVIATION

MISSILE SYSTEMS DIVISION

MINEOLA, LONG ISLAND, N. Y.

Mail Bag

(CONTINUED FROM PAGE 18)

I regretted that the author and/or editor did not see fit to disclose authorship.

I would like to draw the editor's and author's attention to a technical note in the December 1954 issue of the *Journal of the Royal Aeronautical Society*, in which a similar, though more serious discussion of the definition of specific impulse is presented. I note that this discussion is not included in the references of the article in *Astronautics*. It is also unfortunate that mention was not made of the handling of this problem in the American Standard's Association Letter Symbols for Rocket Propulsion. It should be noted that our anonymous author's recommendations do not agree with those of ASA, which is the official position of the ARS, a sponsor of ASA Standards.

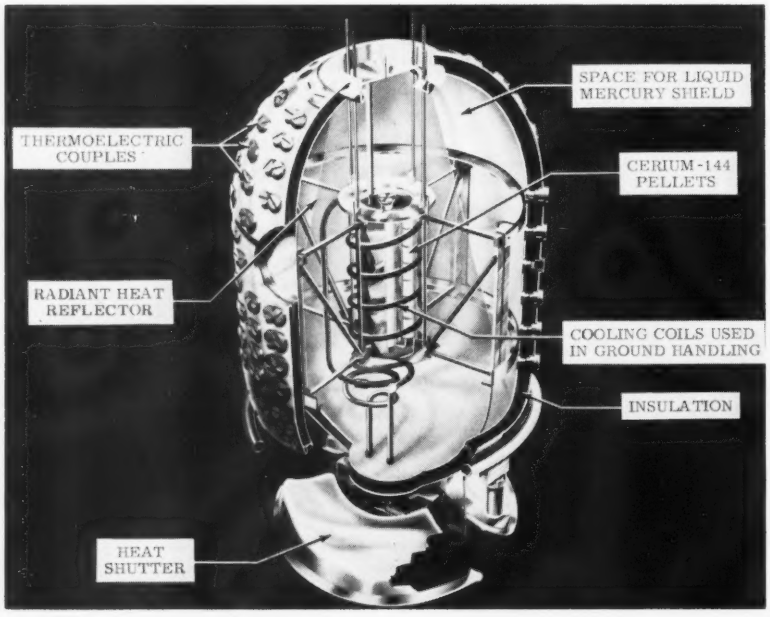
Personally, I agree with your author. In fact, I would go further and encourage (as in the *J. Roy. Aero. Soc.* note) dropping the concept of specific impulse entirely, since it derives its usefulness purely through its relation to the effective exhaust velocity. In trajectory problems it is always converted to effective exhaust velocity anyway. However, the ASA committee would not buy this argument, saying that it was too much of a break with entrenched practice. However, the committee was alert to the problem of dependence of weight on gravitational field strength and defined specific impulse in terms of "standard gravity weight" or "earth weight" so that specific impulse would not depend on gravitation field strength. The cancellation of force units in the numerator and weight units in the denominator was more easily rationalized under these conditions, so the committee came up (over my dead body) with units of "seconds" for specific impulse. It's a shame the anonymous author didn't tie his arguments more effectively to these references, events, and discussions!

I note in your June Mail Bag that there is continuing dissension on the issue of specific impulse. The arguments are familiar and, unfortunately, continue to ignore the existence of ASA Standards. For the record, it seems that Greenwood confuses "units" with "dimensions," claiming that the use of units Lb, ft, sec, and lb gives physical meaning to specific impulse, while use of effective exhaust velocity in ft/sec (which has the same dimensions as his specific impulse) gives something which "has little direct significance." To me it seems the two concepts are equivalent, except that specific impulse uses the "bastard English system of *units*" (Lb, ft, sec, lb), while effective exhaust velocity uses the "nonbastard" English system (Lb, ft, sec, slug or poundal, ft, sec, lb). Both have the *dimensions* L/T. Greenwood's treatment of specific impulse conforms to the treatment by *Astronautics'* anonymous author, but does not conform to ASA Standards.

In the same June issue of Mail Bag, Black extolls the virtues of a definition of specific impulse yielding units of seconds. The arguments are essentially those which led the ASA Committee on Letter Symbols for Rocket Propulsion to adopt that convention. Unfortunately, Black does not take note of the complications following from the effect of a changing gravitational field on weight, as was done by ASA. Thus he leaves himself open to one of the very criticisms leveled by the anonymous author.

In summary, the subject of specific impulse was deliberated long and vehemently by the Letter Symbols Committee, and their compromise decision corrects all downright abuses while leaving both concepts I_{sp} and v_e well defined, reasonably well justified, and consistent with widely accepted usage. The recent paper and communications in *Astronautics* rehash the issue without reference to ASA Standards, and hence serve mainly to further confuse an almost-settled issue. As a sidelight, it is interesting to note that the symbols I_{sp} and v_e used in the discussions noted above are also inconsistent with the ASA standard.

E. W. PRICE
Head, Aerothermochemistry Group
U. S. Naval Ordnance Test Station



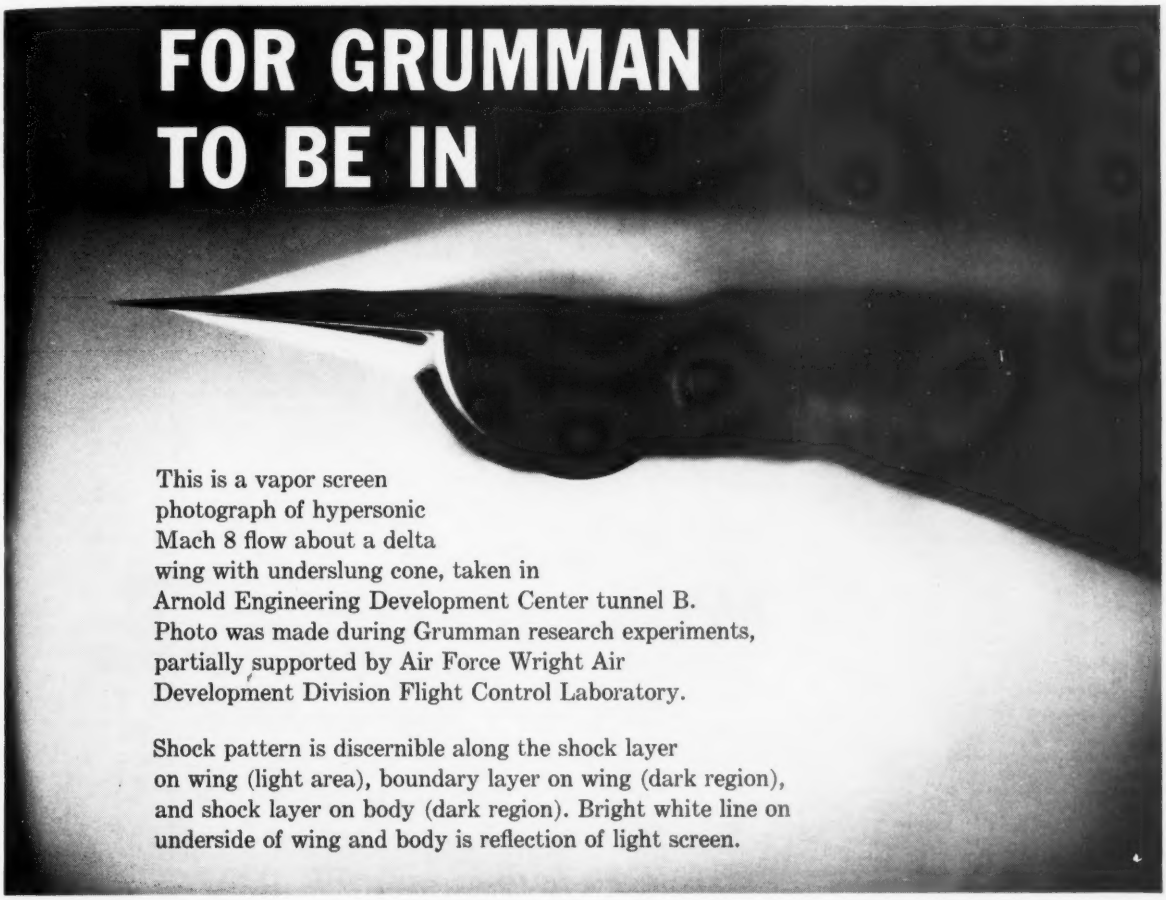
Martin Testing Snap 1A

The cutaway sketch illustrates the design of the 125-watt nuclear-power capsule Snap 1A, which the Martin Co.'s Nuclear Div. has developed and is now testing for the AEC. The system measures roughly 34 in. long by 24 in. in diam and weighs 175 lb. Its shutter releases heat from the decay of the radioactive element at a rate that maintains electrical output constant for a year. According to Martin, tests have already shown conclusively that the radioisotope in Snap 1A would not be released if a rocket carrying it as part of a satellite exploded on the launching pad or failed to reach orbit. The interior of Snap 1A can be filled with mercury to act as a radiation shield.

"Big Daddy" Falcon

Packing a nuclear warhead, the radar-guided Hughes' Gar-11, shown at left, will soon join the Falcon family at right—back to front, radar-guided Gar-1D, IR-guided Gar-2A, and radar-guided Gar-3—in the Air Force's air-to-air missile arsenal. Hughes will manufacture the 7-ft Gar-11 at its Tucson, Ariz., plant under a $23 million AF contract. Expected to be delivered late this year to Air Defense Command units equipped with the F-102 all-weather interceptor, this "Big Daddy" Falcon will give the Air Force a new capability in head-on attack of supersonic aircraft.

NOTHING IS TOO FAR OUT.... FOR GRUMMAN TO BE IN



This is a vapor screen photograph of hypersonic Mach 8 flow about a delta wing with underslung cone, taken in Arnold Engineering Development Center tunnel B. Photo was made during Grumman research experiments, partially supported by Air Force Wright Air Development Division Flight Control Laboratory.

Shock pattern is discernible along the shock layer on wing (light area), boundary layer on wing (dark region), and shock layer on body (dark region). Bright white line on underside of wing and body is reflection of light screen.

This photo characterizes the work Grumman is doing in hypersonic aerodynamics. Other efforts at Grumman include continuing design and development work on orbiting observatories, interplanetary communication systems, re-entry vehicles and reconnaissance satellites, to name a few.

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(CONTINUED FROM PAGE 81)

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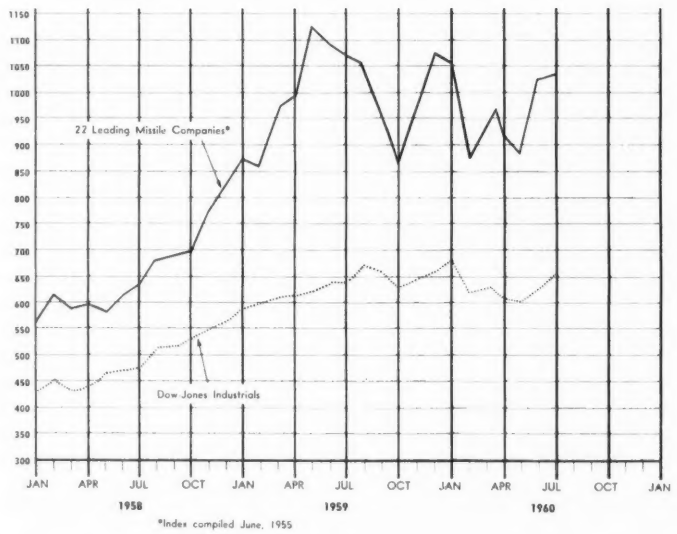
Missile market



*Index compiled June, 1955

	July 1960	June 1960	% Change	July 1959	% Change
Dow-Jones Industrials	655	626	+4.6	644	+1.7
Missile Index	1035	1024	+1.1	1071	−2.1

NEW PRODUCTS CATALOGUE

EQUIPMENT . . . PROCESSES . . . MATERIALS . . . LITERATURE

Connectors

Sleeve and Boot. For protecting piston rods, rams, jacks, and drives; coated nylon withstands range from —80 to 220 F without cracking. **A & A Mfg. Co.,** Milwaukee, Wis.

Joint. Connect multiflapper check valves in airborne pneumatic and fuel systems; easily installed; substantial reduction in weight and envelope size. **Aeroquip Corp.,** Marman Div., Los Angeles, Calif.

Self-Sealing Coupling. Connects and disconnects with one-hand movement; positive action verified by audible click and protruding pins; withstands 20 g. **Aeroquip Corp.,** Jackson, Mich.,

Umbilical. Mating and unmating accomplished without tools; 300 contacts, each rated 5 amp, and two fluid lines, mount in space 2/34 in. sq. **Arnoux Corp.,** Los Angeles, Calif.

Plug and Contact. High electrical performance; 10, 16, 28, 34 and 50 contact layouts; accommodates #26 gauge wire; white polyester insulation. **Cannon Electric Co.,** Los Angeles, Calif.

Rack and Panel. Rectangular; 48 or 63 contact; 59 Size 20 snap-in and 4 Size 16 contacts, or 43 Size 20 and 5 Size 16 snap-in contacts. **Consolidated Electrodynamics Corp.,** Pasadena, Calif.

Ball-Contact. Ductile contact materials, including fine and coin silver and conmet; in six standard sizes from 0.028 to 0.188 in. **Contracts, Inc.,** Wethersfield, Conn.

Fasteners. Pawl-Loc quick-release pin uses pawl as locking element; cannot release accidentally; Zip-Loc stressed panel fastener has high load capabilities. **Deutsch Fastener Corp.,** Los Angeles, Calif.

Locking-Insert. Mounting and locking device combined in one unit; forged-aluminum single and double fasteners in various lengths in increments of 0.10 in. **Heli-Coil Corp.,** Danbury, Conn.

Separation-Nut. Mechanical separation activated by small explosive charge; used in combination with standard high-strength bolts; captive and noncaptive types. **HiShear Rivet Tool Co.,** Torrance, Calif.

Bellows. Machined sections for pressure of 1400 psig with gas temperatures to 1200 F; assemblies allow 0.11 in. for 5 in. of offset movement. **Hydrodyne Corp.,** N. Hollywood, Calif.

Fluid-Coupling. For AN flared-tube, pipe, hose, and special connections; 1/4 through 3 in.; aluminum, stainless steel, carbon steel, or plastic. **Jack & Heintz, Inc.,** Cleveland, Ohio.

Floating-Fastener. Self-clinching, for providing load-bearing threads in thin metal; captive nut allows up to 1/32-in. adjustment; thread sizes 4 to 10. **Penn Engineering & Mfg. Corp.,** Doylestown, Pa.

Pipe. Transition couplings for joining stainless-steel to aluminum pipe without flange or gasket; metallurgically bonded metal. **Project Fabrication Corp.,** College Point, N.Y.

Cable-Plug. Eliminates adapter; goldplated; sizes for all subminiature cables, in two styles, bayonet and threaded. **Sealectro Corp.,** Mamaroneck, N.Y.

Bulkhead-Adaptor. Right-angle adapter permits use of miniature coaxial cable; impedance of 50 ohms. **Sealectro Corp.,** Mamaroneck, N.Y.

Cable-Plug. Fits all subminiature cable sizes; two styles, for bayonet-lug BNC panel connectors and threaded-type; goldplated. **Sealectro Corp.,** Mamaroneck, N.Y.

Flexible-Shaft. Stainless steel, 1/2 or 3/8 in. in diam; operates at 1000F; square ends; lengths to suit. (Illustrated.) **Stow Mfg. Co.,** Binghamton, N.Y.

Microminiature. Series 4A has up to 7 contacts within 1/2-in. diam; variety of mounting styles and in glass-seal types; shell sizes up to 19 contacts. **Viking Industries, Inc.,** Canoga Park, Calif.

Coaxial-Cable. K-grip eliminates need for captive contact; soldering not needed on connectors with brass center contacts; simple crimping; ready inspection. **Kings Electronics Co., Inc.,** Tuckahoe, N.Y.

> Additional information about any of the products, equipment, processes, materials and literature listed on these pages may be obtained by writing to the New Products Department, ASTRONAUTICS, 500 Fifth Avenue, New York 36, N. Y.

Lights

Integral-Lighting. For instruments; wedge-shaped glass and individually wired strings of bulbs, retained by a bezel. **Burton Mfg. Co.,** Instruments Div., Santa Monica, Calif.

Indicator. High-impedance, low-voltage, miniature transistorized neon-type; 6-, 8-, or 10-v supply sources at 50 ma; diam, 1/2 in; length 2 in. **C&K Components, Inc.,** Newton, Mass.

Placard. Illuminate rectangular legend plates which act as lenses; maximum legend area, 13/16 x 9/32 in; lamps removable from panel front. **Dialight Corp.,** Brooklyn, N.Y.

Switchlite. Replaceable high-brightness lamp with plastic lens; 28-v DC; 4-amp inductive (sea level); 2.5-amp inductive (50,000 ft). **Eldema Corp.,** El Monte, Calif.

Colorlite. Unit is white when unlit, and colored (red, white, blue, green, or amber) when lighted; mounts in 9/16-in.-diam hole. **Sloan Co.,** Colorlite Div., Sun Valley, Calif.

Electronic-Indicator. Standard 4- to 28-v sizes; ratings, 35 to 45 ma; foot-candles illumination range from 200 (4v) to 1285 (28v); rated life, 5000 hr. **Sylvania Electronic Products, Inc.,** New York, N.Y.

Motors

High-Torque. Operates from 60-cycle power source; delivers 6 in-lb torque at 20 rpm for a 0.75-amp, 115-v output; wt, 10 oz. **Airborne Accessories Corp.,** Hillside, N.J.

Rotary-Drive Actuator. Slip-clutch gear motor to drive safe/arm mechanisms; develops 1.0 in-lb torque over wide range of conditions; drives a 1.5 in-lb load 90 deg in 55 ms; wt, 8.5 oz. **Bendix Aviation Corp.,** Pacific Div., N. Hollywood, Calif.

High-Temperature Polarized Torque. Provides proportional output force or motion with up to 0.010-in. linear stroke; torque output 0.017 in-lb at 1200 F for 20-hr (minimum). (Illustrated.) **Bendix Corp.,** Pacific Div., N. Hollywood, Calif.

Writing-Pen. For ink writing on rectangular coordinates; records signals from DC to 100 cycles; coil resistance 16-ohms DC; natural frequency, 45 cps; wt, 1.5 lb. **Cohu Electronics, Inc.,** Massa Div., Hingham, Mass.

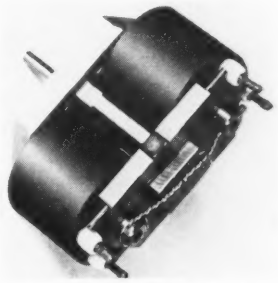
High-Torque. Current consumption nearly constant; useful where current availability is limited (i.e.: solar cell or battery); 85 milliamp running and starting current; diam, 1 3/8 in.; length, 2.25 in.; wt, 12 oz. **Cook Electric Co.,** Diaphlex Div., Chicago, Ill.

Synchronous. Two indentical counter-rotating motors in housing; very slow variable speed; with 60.6-cps current applied, shaft speed is 18 rpm; at 66 cps, shaft speed is 180 rpm; 1/50 to 1 hp. **Genisco, Inc.,** Bekey Electric Div., Los Angeles, Calif.

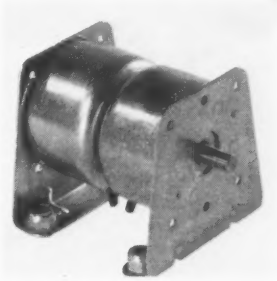
Miniature. Epoxy encapsulated; develops 3/4 oz-in. torque at 1800-rpm synchronous speed; normally wound for 110-v AC, 60 cycles. **Globe Industries, Inc.,** Dayton, Ohio.

Stepping. Unidirectional or bidirectional Size 5 digimotor available with 8, 10, 12, 18, 20, and 24 steps per rev; voltage range from 6 to 350 DC. (Illustrated.) **Ledex, Inc.,** Dayton, Ohio.

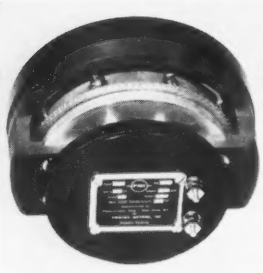
Flex-Shaft Connector



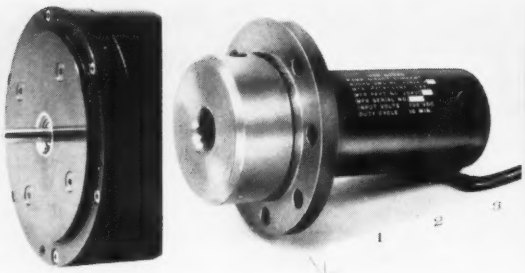
High-Temperature Torque



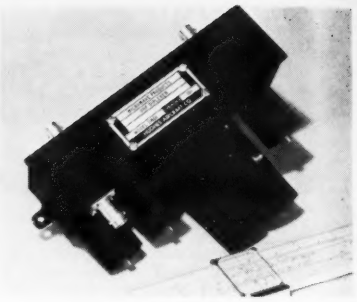
Size 5 Stepper



Printed-Circuit Motor



Impeller



UHF Diplexer

Printed-Circuit. Motor for servo and instrument use employs flat printed circuit; pancake-shaped; light weight permits reaching full speed in a few thousandths of second. (Illustrated.) **Photocircuits Corp.,** Glen Cove, N.Y.

Pump. Spline coupling connects pump directly to motor shaft; uses no mounting platform; ratings from 0.5 through 10 hp. **Reuland Electric Co.,** Alhambra, Calif.

Slo-Syn. Synchronous constant speed, 72 rpm; input 120-v $^{40}/_{70}$ cycles, 1 phase, 0.30-amp max current (at 60 cycles); 50 oz-in. torque; reduction assemblies for various speeds. **Superior Electric Co.,** Bristol, Conn.

Synchronous. Frequency 400 cps; power input, 2.5 watts max; speed, 300 rpm; voltage, 115 v; torque, $^1/_{400}$ oz-in. min; rotation, reversible; wt, 1.7 oz. **Waltham Precision Instrument Co.,** Waltham, Mass.

Pumps

Centrifugal. Operate with heads from 30 to 50 ft at rates from 20 to 3500 gpm; in 3500 rpm and 1750 rpm models. **J. C. Carter Co.,** Costa Mesa, Calif.

Vacuum Ion. DriVac eliminates pressure surger in pumping inert gases; pumps air at 25 liters/sec, argon at 8 liters/sec, methane at 28 liters/sec, and hydrogen at 15 liters/sec; wt, 90 lb. **Consolidated Vacuum Corp.,** Rochester, N.Y.

Gear. Light, low-cost pump delivers 1 gpm at 1500 psi; mount fits standard engine pads; may be installed in any position. **Eastern Industries, Inc.,** Hamden, Conn.

Centrifugal. Stainless steel open impeller type driven by an integral $^1/_{10}$ hp enclosed ball-bearing motor; wt, 6 lb; flow, 3 gpm; pressures to 15 psig. **Eastern Industries, Inc.,** Hamden, Conn.

"Canned." Sealless leakproof unit; wt, less than 7 lb; capacities up to 840 gpm; produces heads up to 9 ft; suitable for specific gravities to 1.5. **Fostoria Corp.,** Chempump Div., Huntington Valley, Pa.

Vacuum Pumps and Air Compressors. Two types available in five rotary-vane models; oilless; carbon vanes lubricate themselves, producing oil-free air blast or exhaust. **Gast Mfg. Corp.,** Benton Harbor, Mich.

Langdon-Vacuum. Operating at 1725 rpm, has capacity of 35 liters pm (free air) and produces an ultimate vacuum of 50 microns. **Hevi-Duty Electric Co.,** Div. of Basic Products Corp., Milwaukee, Wis.

Mercury Piston Compressors. Develop high pressures in various ranges up to 60,000 psi for use with costly gases; mercury displaced by a hydraulically separated oil pump. **High Pressure Equipment Co.,** Erie, Pa.

Impeller. This heavy-duty centrifugal unit delivers up to 8 gpm at 150 psi; handles salt water and other corrosive fluids; duty limit, 10 min. (Illustrated.) **Hydrodyne Corp.,** N. Hollywood, Calif.

Dry Vacuum. Avoids oil consumption; rated capacity at 4.5 Hg and 1500 rpm is 4 cfpm of dry air; wt 3.6 lb. **Randolph Mfg. Co.,** E. Cleveland, Ohio.

Air Hydraulic Boosters. Compressed air at 80 psi boosted up to 3000 psi hydraulic pressure without additional power or need for pumps or motors. **The S-P Mfg. Corp.,** Cleveland, Ohio.

High-Flow Lox. For testing rocket engines; high-flow continuous or intermittent duty for Lox, LN_2, and other cryogenic service at test stands and laboratories. **Turbocraft, Inc.,** Pasadena, Calif.

Electronic. Used in vacuum tube and semiconductor processing, thin films, and particle accelerators; cold-cathode discharge in a magnetic field removes gas molecules and atoms. (Illustrated.) **Ultek Corp.,** Palo Alto, Calif.

Servos

Velocity-Damp Servomotor. Size 18 VM, damps by magnetic coupling of drag cup to magnetic field; adjustable from 75 to 600 dyne-cm-sec per radian. **Beckman Instruments, Inc.,** Helipot Div., Fullerton, Calif.

Gearhead. Transmission unit $^1/_2$ in. in diam, $^3/_4$ in. long; produces step-up or step-down ratios of from 10:1 to 2025:1. **Bomar Instrument Corp.,** Ft. Wayne, Ind.

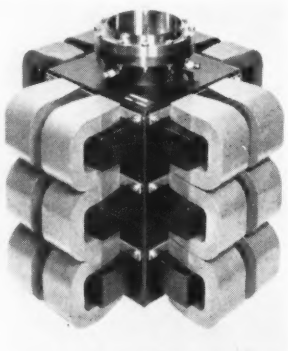
Gearhead. Model G-21A has starting torque of 0.005 in-oz max, and output torque of 50 in-oz (running) and 70 in-oz stalled. **Feedback Controls, Inc.,** Natick, Mass.

Generator. Motor-damping, Size 8 unit with high generator output; 100:1 signal-to-noise ratio; phase shift, zero deg; linearity 2 per cent; wt, 3.9 oz. **General Precision Inc.,** Kearfott Div., Little Falls, N.J.

Line of Gearheads. Series 11 available in over 1000 ratios from 5:1 to 78,125:1; units are $2^{47}/_{64}$ in. long and weigh 6 oz. Max torque load, 100 oz. in. **Guidance Controls Corp.,** Hicksville, N.Y.

System. S-14 system gives less than 3-per cent variation in controlled level for system resonances up to 50 db; reaction time, 3 cycles for 90-per cent correction of 10-per cent gain reduction. **Ling-Altec Electronics, Inc.,** Anaheim, Calif.

Repeater. Subminiature 26-v synchro-servo repeater has static accuracy of 0.24 deg (max) at a 7-min synchro input; velocity constant, 500 deg/sec/deg; slow velocity, 30 rpm. **Orbit Instrument Corp.,** Syosset, N.Y.



Electronic Pump

Planetary and Spur Gearheads. Torque ratings 25 to 40 oz-in.; lengths 0.500 to 1.250 in.; ratio ranges up to 37:1 in 5 ranges to 1201 4000:1. **U.S. Gear Corp.,** Wakefield, Mass.

Switches

Transwitch Series. PNPN silicon switching devices with voltage ratings up to 200. **Transitron Electronic Corp.,** Wakefield, Mass.

Temperature Control. Enables an accurate mercury tube to switch loads up to 10 amp at 28 v DC with no moving parts; transistorized. **Vap-Air Div., Vapor Heating Corp.,** Chicago, Ill.

Telemetry Equipment

Modular Mounting Units. For rapid assembly of multichannel systems with subminiature components; two models, accepting six and eight components; wiring and connectors self-contained for plug-ins. **Bendix-Pacific Div.,** North Hollywood, Calif.

Test Oscillator. For calibration of subcarriers in Polaris FM/FM telemetering systems; supplied with any 20 frequencies from 20 cycles to 100 kc; pushbutton selects frequencies. **Crosby-Teletronics Corp.,** Westbury, N.Y.

Command Receiver. Fully transistorized, matchbox-size unit with four channels; withstands 100-g acceleration and shock; temp range of —40 to 70 C. **Avco Crosley Div.,** Cincinnati, Ohio.

UHF Diplexer. Permits a 100-watt transmitter and sensitive receiver to be operated together with a single antenna in the 225-400 mc band; isolation over 100 db; insertion loss only 0.2 db; wt, less than 1 lb. (Illustrated.) **Hughes Aircraft Co.,** Culver City, Calif.

UHF Command-Destruct Receiver. Transistorized; operates in 400 to 550 mc range; sensitivity of 5.0 microvolts; vol., 16.8 cu in.; wt, 1 lb. **R S Electronics Corp.,** Palo Alto, Calif.

Signal Simulator. Simulates PAM pulse train for calibration and checkout of ground stations; IRIG standards between 6 and 3600 pps; fits standard 19-in. relay rack. **Telemetrics Inc.,** Northridge, Calif.

Digital Commutator. Solid-state design; accepts, converts, digitalizes, corrects, and displays most existing or proposed pulse-type signals; 48 channel unit takes $52^1/_2$ in. of rack. **Electro-Mechanical Research Inc.,** Sarasota, Fla.

Subcarrier Discriminator. Solid-state, phaselock design with true 60-db dynamic-input voltage range; each subcarrier signal amplitude up to 10 v in multiples of 18. **Electro-Mechanical Research Inc.,** Sarasota, Fla.

Multicoder. Silicon solid-state design; two high- and two low-level commutators, two power supplies, inverter, amp gate, and probe in one package $8 \times 3^1/_4 \times 2^1/_2$ weighing $5^1/_4$ lb. **General Devices Inc.,** Princeton, N.J.

Low-Level Commutators. Solid-state design; for airborne sampling of low-level differential instruments; up to 90 channels; samples at rate up to 10,000 per sec with accuracy of 1% or better. **General Devices Inc.,** Princeton, N.J.

Subcarrier Oscillators. Series of wideband modules of v-sensing, FM type for recording DC or AC signals on magnetic tape; center frequencies between 500 cps and 54 kc/s; wt, 3 oz. **General Devices Inc.,** Princeton, N.J.

Broadband Receivers. Series of "wide open" broadband pulse receivers, three of which cover the entire 45 to 10,750 mc spectrum with sensitivity approaching superhetrodyne equipment. **Granger Associates,** Palo Alto, Calif.

Transient Timer. Allows transmission over a bandwidth of a few cycles the instant a transient occurs; compatible with all standard telemetry systems; temp range, 0-165 F. **Gulton Industries,** Metuchen, N.J.

Bandswitch Discriminator. A phaselock capable of selecting any of the standard telemetry channels for data reproduction; sensitivity from 10 mv rms to 14.5 kc, and 70 mv rms at 70 kc. **Hallamore Electronics Co.,** Anaheim, Calif.

Precision Subcarrier Oscillator. Model 10087, for channels 8-18, offers a linearity within 0.1% of bandwidth; frequency and sensitivity within 0.3% between 0-85 C. **Hoover Electronics Co.,** Timonium, Md.

Television

Closed-Circuit. Inspection machine on pipe frame 6 x 8 x 3.5 ft high; camera enlarges field of view 30 times; two readings gives a true dimension. **Cohu Electronics, Inc.,** Kintel Div., San Diego, Calif.

Three-Dimensional. Overlapping images from two cameras and polarized optical system; monitors from 8 to 27 in. **Cohu Electronics, Inc.,** Kintel Div., San Diego, Calif.

Projection. A major system for display data; self-contained unit 63.25 x 41.25 x 25 in.; control layer modulates light from high-intensity Xenon lamp. **GE Communications Products Dept.,** Lynchburg, Va.

Camera. Permits close inspection of nuclear reactors; allows atomic radiation to pass through it without harm; made of aluminum, magnesium, silicon, titanium, and zirconium; circuitry has six ceramic components. **ITT Corp.,** New York, N.Y.

Slow-Scan Transmission. TV relay of maps, charts, and pictures flashed to a receiving center using existing telephone lines or transoceanic cables. **ITT Corp.,** New York, N.Y.

"Cameraless." Closed-circuit system uses no camera lights or optical system; simultaneous visual communication with up to 500 locations. **Television Utilities Corp.,** Div. of Nord., New Hyde Park, N.Y.

Ruggedized System. Model RGS-10 consists of camera and control capable of operation 2000 ft apart; camera wt, 15 lb; control wt, 15 lb; withstands extreme environment. (Illustrated.) **Thompson Ramo Wooldridge, Inc.,** Dage TV Div., Michigan City, Ind.

Thermocouples, Probes

Resistance Sensor. Used to measure leading-edge temperature of B-58 wing; 1/4 x 1/8 in.; calibrated at several points between 100 and 400 F; accurate to 0.1%. **Dale Products Inc.,** Columbus, Neb.

Six-Ft-Stem Thermometer. For deep vats and the like; temp ranges from 0-200 to 200-1000 F; hand-calibrated for accuracy within 1% of full scale. **Dillon and Co.,** Van Nuys, Calif.

Surface Probe. A bead thermistor mounted on an aluminum disc 1/4 in. in diam and 0.005 in. thick; standard responses from 0-350 F. **Fenwal Electronics Inc.,** Framingham, Mass.

Reference Junction. A 15-channel thermocouple reference junction compensator that eliminates ice-bath reference in calibration; allows remote location of thermocouples; wt, 1 lb. **Harco Laboratories, Inc.,** New Haven, Conn.

Caibration Stand. Meets thermocouple calibration requirements of MIL-E-5009B for jet engine pre- and post-acceptance tests. **Harco Laboratories Inc.,** New Haven, Conn.

Custom-Built Probes. Expanded-scale thermometers, based on the Beckman Expanded Scale Meter, in a variety of models—portable, panel-mounted, probe, etc.; accuracy to ±0.5 C. **Helipot Div., Beckman Instruments Inc.,** Fullerton, Calif.

Precision Probes. Precision platinum temperature sensors; nine stem lengths and six different fittings; range from —435 to 500 F. **Rosemount Engineering Co.,** Minneapolis, Minn.

Liquid-Hydrogen Probe. Miniature platinum resistance thermometer specifically designed to make rapid and accurate measurement of liquid-hydrogen temperature; stainless-steel sheath 2 1/4 in. long. **Trans-Sonics Inc.,** Burlington, Mass.

Miniature Coaxial Thermocouple. In diameters as small as 0.0062 in.; will not melt or break down dialectrically under 3000 F; copper-constantan elements. **Uniform Tubes Inc.,** Collegeville, Pa.

Vacuum Thermocouple Junctions. Some 50 precision-calibrated models in three styles, with sensitivities from 2.5 to 1000 ma full scale; contact and insulated-heater types. **Winslow Co.,** Union, N.J.

Timers

Magnetic-Counter. For digital-readout, statistical, airborne-recording, camera-data, etc. applications; up to 1800 counts/min; for 6, 12, 24, and 110 v. **Abrams Instrument Corp.,** Lansing, Mich.

Transistorized Modules. Series consists of 7 major packages—the flip-flop, 1-shot, diode gates, indicators, or-and inverter, power driver, and analog switch. **ACF Industries, Inc.,** Electronics Div., Riverdale, Md.

Torque-Meter. Transmits signals through 50,000 rpm; Model F2C2A built in ranges from 0 to 100 in/lb full scale through 0 to 1000 in/lb, with 0.6 pd male spline shaft ends. **B & F Instruments, Inc.,** Philadelphia, Pa.

Elapsed-Time. Easily read at 6 ft; numerals 1/8 in. high on black drum; provides readings in 1-hr increments from 0 to 999 hr with return to 0. **Bowmar Instrument Corp.,** Ft. Wayne, Ind.

Missile-"Clock." Model MB400; max power required, 11 watts; 400-cps output a square wave, 2 v peak-to-peak (min), into a 1 kilohm load. **Bulova Watch Co., Inc.,** Electronics Div., Woodside, N.Y.

Digital. Model DET-420; power input 115 v, 400 cps single phase, and 28 v DC (1 amp); output 26 v (0.5 amp max) when not timing; several intervals from 5 to 150 sec can be set. Error less than 100 μ sec. (Illustrated.) **Bulova Watch Co., Inc.,** Woodside, N.Y.

Time-of-Occurrence. Used in Minuteman to make time of events; time can be sent over restricted bandwidth channel of multiplex PDM; about 1 cu in. **Electro-Mechanical Research, Inc.,** ASCOP Div., Princeton, N.J.

Miniature Sequence Programmer. Disk may be divided for sequences requiring up to 100 switch positions; rated for 4 to 8 v; operates with input pulses of 11 ms up to 70 indexing motions per sec. (Illustrated.) **Elgin National Watch Co.** Micronics Div., Elgin, Ill.

Delay. For 28 v DC; contacts dpdt rated for 100,000 operations at 3 amp; wt, 4 oz; transistorized. **G-V Controls, Inc.,** Livingston, N.J.

Stepping. Printed-circuit rotary stepper contains up to 30 positions on single deck; produces up to 2400 steps per min at 24 v DC. **A. W. Haydon Co.,** Waterbury, Conn.

Predetermined-Pulse. Operates only on number of pulses received, not incremental changes in voltage or phase angle; supplied with decimal or angle counters. **A. W. Haydon Co.,** Waterbury, Conn.

Clock. For digital recorders; adds time-of-day data to other recorded information; indicate to 24 hr; fits into cabinet or rack mount. **Hewlett-Packard Co.,** Palo Alto, Calif.

Electronic Counter. Model 523CR, directly measures frequencies from 10 cps to 1.2 mc, time intervals from 1 microsecond to 10^8 sec and periods from 0.00001 cps to 100 kc. (Illustrated.) **Hewlett-Packard Co.,** Palo Alto, Calif.

Programmer. MA-6011 provides control/power signals for test operations in sequence; performs such functions as "and, or, not and memory" in addition to time relay. **Magnetic Amplifiers, Inc.,** New York, N.Y.

Counting. Numerals 4 1/2 in.; accepts input pulses, registers decimal point, and generates an output pulse at count of 10. **Navigation Computer Corp.,** Philadelphia, Pa.

Delay-Relay. Adjustable over a range of 10 per cent above and below normal; delay from 10 to 250 sec; operates on 18 to 32 v DC; over-all accuracy, 2 per cent. **Sloan Co.,** Auto-Timer Div., Sun Valley, Calif.

Transistorized. Multiple-pulsing, period from 0.1 to 1 sec and width from 25 100 ms; handles 25 amp, 32 v inductive over a range of —55 to 125 C; withstands vibration up to 2000 cps and shock of 50 g for 11 ms. **Sloan Co.,** Auto-Timer Div., Sun Valley, Calif.

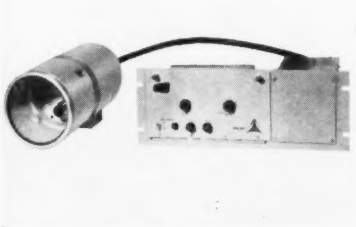
On-Off Programmer. Model 602 for On-Off junctions; 30 circuits, carrying 2-amp resistive; range from 60 to 5000 sec. **Sloan Co.,** Auto-Timer Div., Sun Valley, Calif.

Counter-Timer. Measures frequencies from 0 to 10 mc, intervals from 0.3 μ sec to 10^8 sec, frequencies ratios to 10^7, and phase measurements direct to 0.1 deg; panel height, 5 1/4 in. **Systron Corp.,** Concord, Calif.

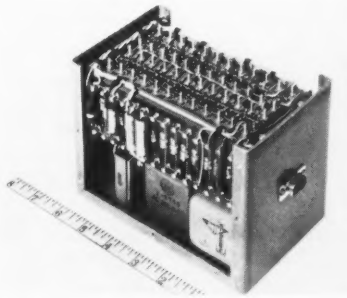
Central System. For range timing systems, time correlation of test data, and central programming units; choice of plug-in logic modules. **Temco Aircraft Corp.,** Electronics Div., Dallas, Tex.

Modules. Individual "building block" components; in fixed-time units with delays from 0.00005 to 300 sec; also adjustable delays from 0.00005 to 0.001 sec. **Temco Instrument, Inc.,** Hicksville, N.Y

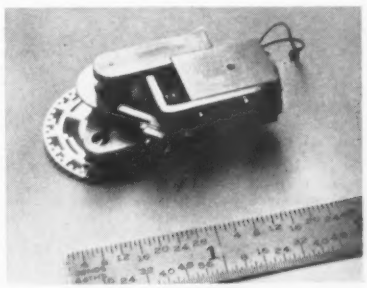
Solid-State Counter-Timer. Totalizes random events over any of 8 time intervals from 10^{-6}



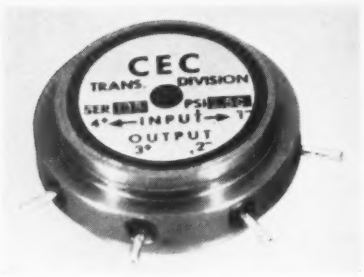
Dage M-RGS-10 TV



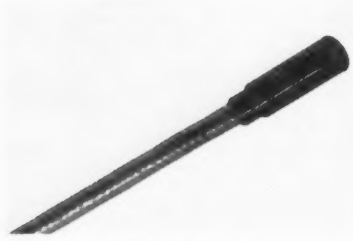
Digital Timer



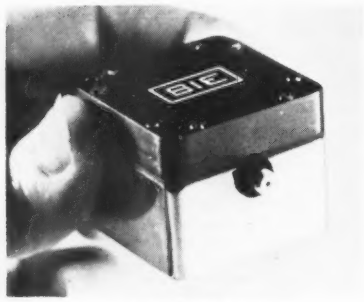
Sequence Programmer



Strain Gauge



Proximity Pickup



Vibration Pickup

to 10 sec; frequency from 0 to 10^6 pulses/sec or 1 to 10^6 cps; power drain, 35 watt; 3 1/2 in. high in standard racks. **Transistor Specialties, Inc.,** Plainview, N.Y.

Solid-State Program. Minichron 10, rugged unit for programming missiles in flight; operates on 22 to 35 v DC; current drain, 0.2 amp; wt, less than 9 lb; pinpoints 16 different operations. **Victoreen Instrument Co.,** Jordan Electronics Div., Alhambra, Calif.

Multi-Unit. Reset timer panel provides automatic control of 8 sequential operations; calibrated from 0 to 60 sec; ranges up to 10 min. **Zenith Electric Co.,** Chicago, Ill.

Transducers

Linear and Rotary Motion. Two models; scale factors of 0.2 and 0.4 v rms/deg, input range of ±30 and ±60 deg; brushless, 1.25 in. high and 0.94 in. in diam; range, 300-3000 cps. **Arnoux Corp.,** Los Angeles, Calif.

Ultrasonic-Testing. Series (White Line) employing ferroelectric elements, available in standard sizes in the 200 kc to 10 mc range, with standard connectors and focal lengths. **Automation Industries,** Boulder, Colo.

Photoelastic Strain Gauge. Direct-reading uniaxial indicators in 3/4 and 2-in. lengths; max strain, 1.5 per cent at 100 F. **BLH Electronics and Instrumentation Div.,** Waltham, Mass.

Angular-Motion. Rugged 3 x 2 1/2 x 2-in. unit weighing 20 oz for operation at 60 cps, converts angular motions up to ± 40 deg with linearity better than 0.25 per cent; scale factor, 0.57 v rms/deg. **Brush Instruments,** Cleveland, Ohio.

Altitude-Control. Model 571, of trapped-air-pressure design, has operating range of 80,000 ft, dynamic error band of ±2 per cent, sensitivity and threshold of 0.2 per cent, response of 50 ms, operating temperature of —65 to 250 F. **Bourns Inc.,** Riverside, Calif.

Angular-Motion. Model 903, sensitive to rotation of 0.012 deg with range of ±3 to ±5 deg; DC output; flat response to 30 cps; rugged and sealed with weight of only 11 oz. **Bourns Inc.,** Riverside, Calif.

Displacement. Line featuring solid-state circuitry; DC-DC; large stroke to length ratios; response beyond 1000 cps; replaces carrier amplifier systems. **G. L. Collins Corp.,** Long Beach, Calif.

Shock-Overload. Action mechanical; red band indicates actuation through plastic dome; 1 1/2 x 1 3/4 in.; weight, 4 oz; easily reset. **E. S. Condon Co.,** Los Angeles, Calif.

Miniature Strain Gauge. Type 4-325 unbonded, 3/4 x 1/3 in. weighing 8 grams, has pressure ranges of ±2 to ±50 psi differential, pressure limit 1.5 times rated without calibration shift, temperature range of —320 to 300 F, excitation of 5 and 12 v rms. (Illustrated.) **Consolidated Electrodynamics Corp.,** Pasadena, Calif.

Variable-Permenance. With spring-loaded probe for continuous-movement uses where probe cannot be coupled to moving member; four models in rated ranges of 0.25- to 2.0-in. displacement. **Crescent Engineering and Research Co.,** El Monte, Calif.

Proximity-Pickup. Oil and waterproof; mounted at point of work, detects metal parts with less than 1/10-in. diam and can be excited by gear teeth of 10 diametral pitch. (Illustrated.) **Electro Products Laboratories, Inc.,** Chicago, Ill.

Thermistors. A series of standardized Type K's available with resistances from 1-100 k at 25 C; operating temperatures to 600 C. **Kidde Aero Space Div.,** Belleville, N.J.

Folded-Filament Strain Gauge. Line of weldable gauges; SS-E-6 a 120-ohm unit less than 1 1/4-in. long, usable to 800 F statically and 1600 F dynamically; of various materials. **Micro-Test Inc.,** Santa Monica, Calif.

Ultrasonic-Cleaning. End-fitting and bulkhead types; input models of 60, 125, and 250 w; barium titanate elements in stainless-steel housings. **National Ultrasonic Corp.,** Irvington, N.J.

Phase-Shifting. Developed for measuring time intervals in radar-ranging systems; no brushes; max operating speed, 5000 rpm. **Nilsen Mfg. Co.,** Addison, Ill.

Ultrasonic Feedback. For cleaning, the Powertron, automatically adjusts phase and frequency; controlled by just on-off switch. **Powertron Ultrasonics Corp.,** Garden City, N.Y.

Vibration Pickup. Ceramic pickup Model 61C operates in high humidities up to 200 F; low frequency response; internal impedance, 10,000 mf at 80 F. **Shure Brothers Inc.,** Evanston, Ill.

Precision Pressure. Series IP-2010 Gauge with full-scale ranges from 0-4 through 0-10,000 psi; absolute and differential from 0-4 through 0-2000 psi; primary sensing element a helical bourdon tube; linearity for all ranges within ±0.3 per cent of full range; resolution within 0.15 per cent of range. **H. E. Sostman & Co.,** Cranford, N.J.

Magnetic-Circuit Vibration Pickup. Combines temperature stability of magnetic damping with sensitivity associated with fluid-damped units; measures near 1 1/2-in. cube and weighs 6.5 oz; frequency range of 20-20,000 cps; threshold velocity virtually zero. (Illustrated.) **Southwestern Industrial Electronics Co.,** Houston, Tex.

Solid-State. Prototypes with thermal coefficient of sensitivity about 0.015 per cent F and thermal zero shift less than 0.01 per cent full scale/F; in the stage of production design; this type of transducer should prove widely popular when available at reasonable cost. **Statham Instruments, Inc.,** Los Angeles, Calif.

Bimetal Disk Thermostats. Type MX, supplied with differentials, as measured on the disk, of 1 to 4 F on special order; standards available with differentials of 2 to 6 F; weight, 5 grams; takes high g. **Stevens Mfg. Co.,** Mansfield, Ohio.

Valves

Single-Flapper Check. Available in several sizes for checking air-conditioning-system ram air, checking air in compartment cooling systems, or in cabin pressurization; internal leakage 0.04 lb/min. **Barber-Colman Co.,** Rockford, Ill.

Flow Tubes. For metering petroleum, chemicals, gases, steam, and other process fluids; sizes 1 to 120 in. in various metals and 10 styles. **B-I-F Industries, Inc.,** Providence, R.I.

Primary Fuel. Squib operated; 1.5 cycle, 3 operation; dual wires for reliability; used in Discoverer. (Illustrated.) **Clary Dynamics,** San Gabriel, Calif.

Hermetic. Suited to hydrazine, nitrogen tetroxide, rocket-engine combustion products, and fuel vapors; all metal; squib-operated. **Dyna-Matics Corp.,** Sun Valley, Calif.

Convertible Bonnet. Sizes 1/4, 3/8, 1/2, and 3/4 in; pressure ratings, 1500 and 2500 lb; allow a chemical processor to upgrade dead-end service. **General Kinetics Corp.,** Englewood, N.J.

Hose. For wash-down and air-blow applications; fits standard 1/2, 3/4, and 1 in. ID hose; special nozzle with 1/2 in. ips can be substituted for solid jet nozzle. **General Kinetics Corp.,** Englewood, N.Y.

High-Pressure Regulator. Small-volume pressure control; metal parts in contact with line fluid are stainless steel; minimum number of parts. **Grove Valve & Regulator Co.,** Oakland, Calif.

Air-Flow Meter. Deadbeat or precise readings; for liquids and gases; revolving drum-type dial gives direct readings on flows from 20 to 200 cfm, and pressures from 2 to 12.5 psig. **Highland Engineering Co.,** Santa Monica, Calif.

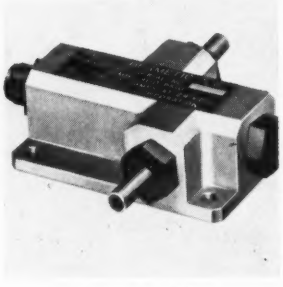
Dual-Coil Pneumatic. For nose-cone attitude control, Model MV-160 actuates electrically to provide 300-psig air to two reaction nozzles for pitch, yaw and roll; wt, 1.7 lb. **Marotta Valve Corp.,** Boonton, N.J.

High-Temperature Gas. Controls gas flow at 2000 F from small solid-propellant generator; Model MV-146G is 2-way, operated on 27 to 35 v DC. **Marotta Valve Corp.,** Boonton, N.J.

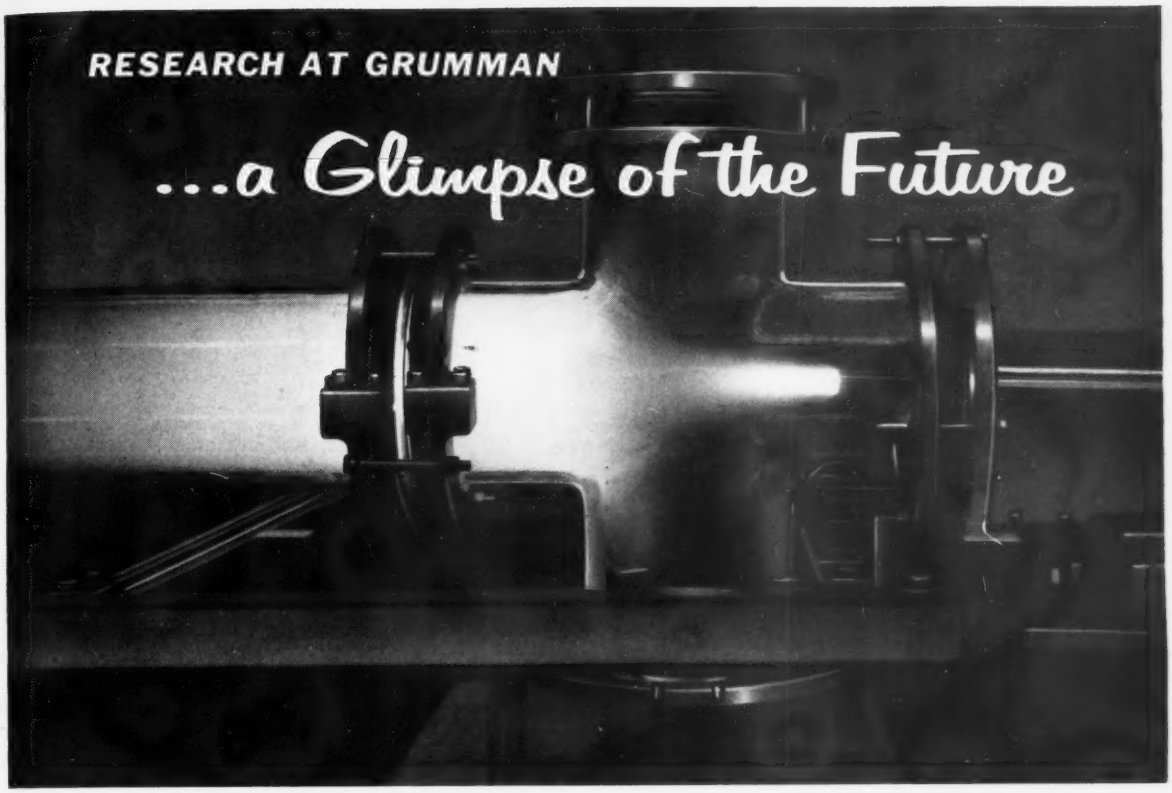
Solenoid-Operated Air. Model 551, 4-way with 1/4-in. manifold base; 2 to 10 may be ganged to form common inlet, exhaust, and conduit channels. **Mechanical Air Controls,** Detroit, Mich.

Pneumatic Regulator. Operating pressure inlet 100 to 20,000 psi; pressure adjustable; flow rate to 100 lb/min. helium with 6000- to 10,000-psi inlet pressure. **Vinson Engineering & Sales Corp.,** Van Nuys, Calif. ♦♦

Primary Fuel Valve



Hermetic Valve



This burst of plasma in the Bostick cell of Grumman's plasma generator is a point of light in the unknown world of plasma. But it is a "Point of Light" which is giving direction to studies in many plasma fields including problems associated with space travel.

Through discharges in the order of 20 joules of electrical energy, in a vacuum of 10^{-6} mm Hg, plasma is created in the accelerator and studied by the use of various diagnostic techniques. Much of this experimental activity concerns the development and refinement of techniques utilizing the Langmuir probe, the ballistic pendulum, and high-speed electronic and photographic methods. In keeping with the basic research nature of the generator, a major part of the activities is devoted to devising new methods of generating and accelerating the plasma and increasing the intensity and duration.

The ability to predict and control the behavior of plasma (a neutral gas which is completely ionized) is one of the most challenging fundamental problems in modern applied physics. In our new Fluid Mechanics and Plasma Physics Research Laboratory, Grumman engineers and scientists are expanding man's spheres of knowledge of plasma, of magnetohydrodynamics, of hypersonic aerodynamics, of the ionosphere, and of numerous related fields. We shall welcome the opportunity to discuss our extensive research activities with men of inquisitive intellect.

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GAS DYNAMICS & HYPERSONICS. Theoretical and experimental research on rarified gas dynamics, gas-surface interactions, aerothermo chemistry and hypersonic aerodynamics, including the use of Grumman's Shock Tunnel, Shock Tube, Plasma Jet and Physical Chemistry Laboratory.

SOLID STATE, NUCLEAR, GENERAL PHYSICS. Theoretical and experimental research in broad areas of field theory, energy conversion, nuclear physics, acoustics, electromagnetic radiation (particularly, but not limited to, micro- and millimeter waves).

MATH—PHYSICS—ELECTRONICS—COMPUTING R & D. Basic research and development in areas such as: airborne and special purpose computing systems, combined analog-digital computation, simulation, programming, mathematical and numerical techniques.

PHYSICAL CHEMISTRY—Materials R & D—Research and advanced development in high temperature reactions, coatings, powder metallurgy, refractory composite structures, ceramics, fatigue and fracture.
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Bethpage, Long Island, N.Y.

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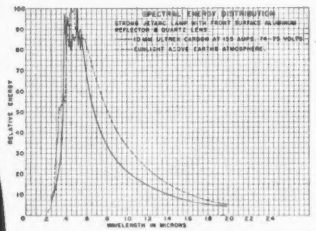

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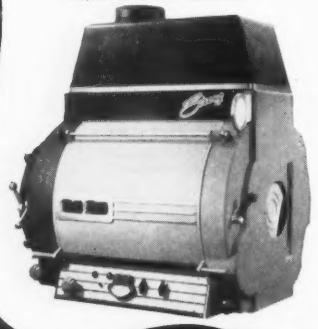

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